INTRODUCTION TO THE CRYSTAL CLASS MODELS

These models can be used in several ways by those who want to:
 1. make interesting shaped boxes
 2. learn about the symmetries of polyhedra
 3. learn to identify crystals and minerals based on the symmetries of their faces

You may want to print this first page on ordinary thickness paper and have it by you for reference when making the models. There are 8 models, one for each of the 7 crystal classes and an extra one as a puzzle for you to identify the class tp which it belongs. After this first page, there are some pages of explanation and exercises for those interested in symmetries, followed by one page for each model with some details and a plan for making the model. Instructions for maing the closed models are on the next page.

Instructions for Making boxes

1. Choose the model to make and copy that page to your own file before decorating the faces of the box electronically with your own clip art or text.
2. Decide how you want to close your box. Most of the models are drawn in the same way on the page, with a face with 3 tabs round it at the top. You can cut off the side tabs to make a face with just one tab which is bent over and tucked in to close the box. Alternatively, you may prefer to make a 'lid' which comes down on the outside of the box. Look at the page 'Lid' to see how to extend the tabs to make a lid which fits on the outside. You may want to decorate these 3 tabs with clip art since they will be on the outside of your box. This method is not convenient for making hexagonal boxes. Future versions of these models will have an alternate plan for a hexagonal box, and instructions for making a separate lid.
3. Print the page on to stiff card or 160gm weight paper in the colour of your choice. The pages are designed for A4 size printers; the plans can be scaled to any size you wish if you have a printer which takes bigger paper.   Changing line width? Tabs don't fit it too thick?
4. Cut out the plan with scissors around the outside solid lines or for a more accurate model, rest the page on a borad to protect your table, and use a steel ruler and a model knife to cut around the outside.
5. Score along all the internal lines using a ruler and compass point
6. Fold **up** along the dashed lines and **down** along the solid ones
7. Now try folding the model along the lines to see how it fits together before gluing, and to decide where to glue a thread if you want to hang up the model. It is easier to choose one of the first corners glued to attach the thread
8. Unfold your model and decorate it with any patterned materials or objects which are easier to glue to the faces at this stage.
9. Use a quick setting model glue to join the tabs to their adjacent faces, remembering to glue your thread on the inside of one of the model faces, or you can make a big knot in the thread to stop it slipping through the hole at the corner. Leave the thread poking out of the corner.
10. Glue the tabs on your 'lid' together

Instructions for Making closed Models

This is simpler than making the boxes described on the previous page, but before starting you may want to look at the next page, which is an explanation of the different classes of crystal, based on the shapes of the faces and the angles between them. You may want to print out this page and the next three for reference while making your models, and for suggested exercises for you to do with the models after they are completed. Each of the last pages has the plans for a model and a few details about it.

1. Print the page for your chosen model on to stiff card or 160gm weight paper in the colour of your choice. The pages are designed for A4 size printers; the plans can be scaled to any size you wish if you have a printer which takes bigger paper. Changing line width? Tabs don't fit it too thick?

4. Cut out the plan with scissors around the outside solid lines or for a more accurate model, rest the page on a borad to protect your table, and use a steel ruler and a model knife to cut around the outside.

5. Score along all the internal lines using a ruler and compass point

6. Fold *up* along the dashed lines and *down* along the solid ones

7. Now try folding the model along the lines to see how it fits together before gluing, and to decide where to glue a thread if you want to hang up the model. It is easier to choose one of the first corners glued to attach the thread

8. Unfold your model.

9. Use a quick setting model glue to join the tabs to their adjacent faces, remembering to glue your thread on the inside of one of the model faces, or you can make a big knot in the thread to stop it slipping through the hole at the corner. Leave the thread poking out of the corner.

10. Look at the details about the model printed with the plan, and make sure you can find the positions of all the axes of symmetry listed. You may want to draw the appropriate symmetry symbols in the right place on your model in pencil so that you can erase them and test yourself again later.

11. Mineralogists should name a mineral which crystallises in this class

12. Make the other models in the same way

Exercises when you have made all the models

On the two pages following this one there are shaded 3D views of all the models shown from different view points. Use your set of models to identify the view points and answer the questions.

Useful Books

1. "A guide to Understanding crystallography", Jennie R.Smith, 1991 A special publication of the Rochester Mineralogical Symposium, This book is intended for mineral collectors.

2. "Crystals and Crystal growing", Alan Holden and Phyllis Morrison, MIT Press edition 1992 ISBN 0 262-58050-0 pbk. This book is for adults; it explains many details about crystals and thier shapes

3. "Crystals " Gordon Cressey and Ian Mercer, 1999 published by the Natural History Museum, London ISBN 0 565 09145 X

4. Hammond

The 7 crystal systems

Crystals can be thought of as being made of very small building blocks; repeating the block many times will make the crystal big enough for you to see.   If you make models of these blocks and build your own model crystal, you will find that the blocks fit together leaving no gaps. Crystallographers call the blocks 'unit cells'.
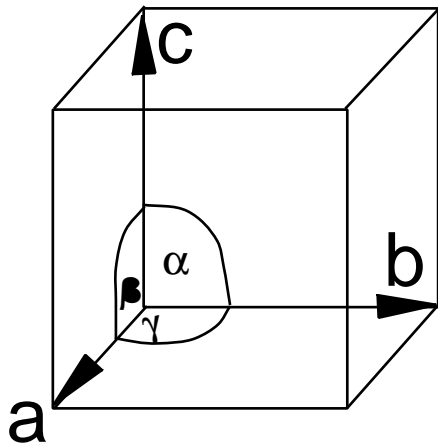
The unit cell has edges of lengths a, b, c and the angles between the edges are α , β , γ as shown in the diagram.

The particular cases when some sides are equal and some angles equal have special names as listed below.

In these models sides are made from squares, rectangles, rhombuses or hexagons.

System	edge (Axial) lengths and angles		no.	symmetries
Cubic (isometric)	a = b = c	$\alpha = \beta = \gamma = 90^{\bullet}$	4	3-fold
Tetragonal	a = b ≠ c	$\alpha = \beta = \gamma = 90^{\bullet}$	1	4-fold
Orthorhombic	a ≠ b ≠ c	$\alpha = \beta = \gamma = 90^{\bullet}$	3	2-fold
Trigonal	a = b = c	$\alpha = \beta = \gamma \neq 90^{\bullet}$	1	3-fold
Hexagonal	a = b ≠ c	$\alpha = \beta = 90^{\bullet}, \gamma = 120^{\bullet}$	1	6-fold
Monoclinic	a ≠ b ≠ c	$\alpha = \gamma = 90^{\bullet}, = \beta > 90^{\bullet}$	1	2-fold
Triclinic	a ≠ b ≠ c	$\alpha \neq \beta \neq \gamma \neq 90^{\bullet}$		no axes

Crystals are assigned to a system, based on how many rotational symmetries they have.
This means that models which have different shapes, can belong to the same system,
both a cube(1) and a octahedron(5) have the same symmetries and belong to the 'cubic' system.

1.   2.   3.   4.   5.
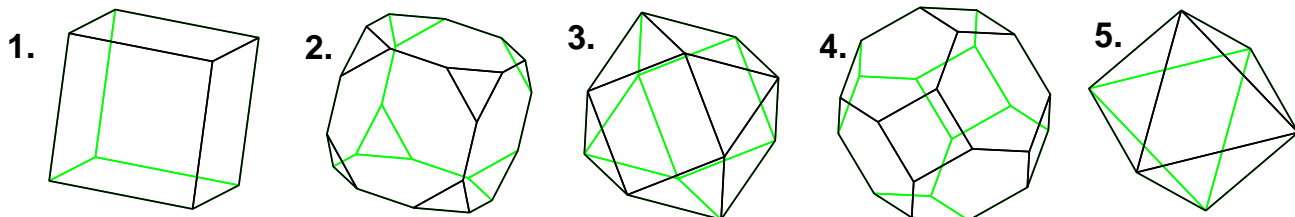
the diagrams show different forms in which the mineral galena crystallises, starting from the cube and making bigger cuts across the corners each time, you make 2,3,4 and finally the octahedron. What rotational symmetries do 2,3,4 have?   What are their polyhedral names?

For any model look for axes of rotational symmetry, first those passing through faces, then those passing through edges and lastly those through corners.

Identify the Symmetry Axes

The diagrams on this page and the next show views of the models from different directions.
There are 4 views for each model, arranged in a row and labelled A,B,C,D
Answer the following questions: for each row:

What is the name of the model?

How may rotational symmetries does it have?

What axis of rotational symmetry (if any) is shown?

Draw the relevant rotational symmetry symbol (if any) on the position of the axis.
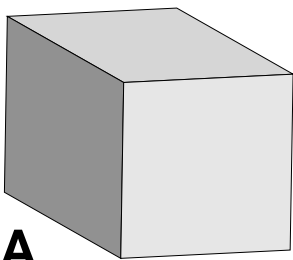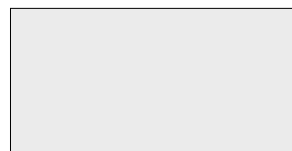
What axis of reflection symmetry (if any) is shown?

Symmetry Symbols

2 fold rotation

3 fold rotation

4 fold rotation

6 fold rotation

A   B   C   D

A   B   C   D

A   B   C   D

A

B

C

D

A
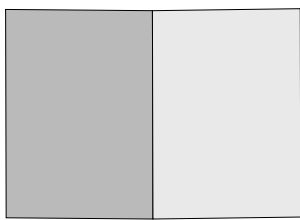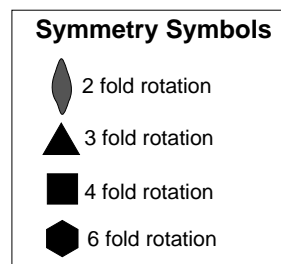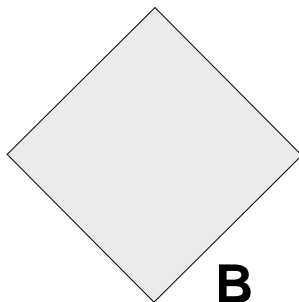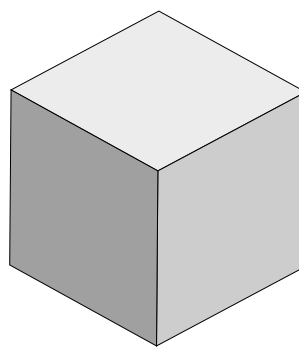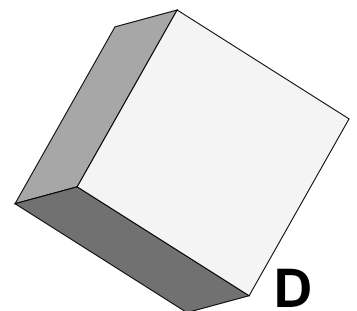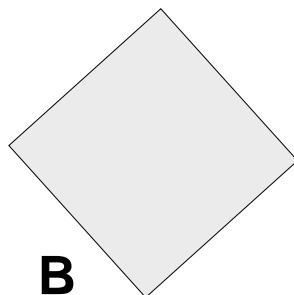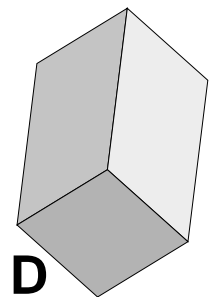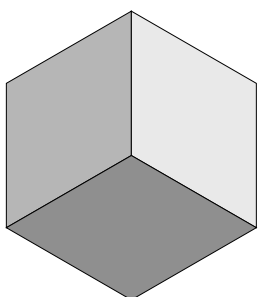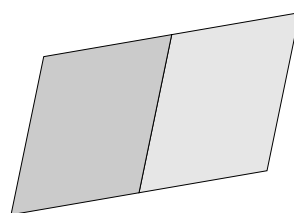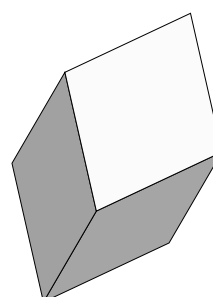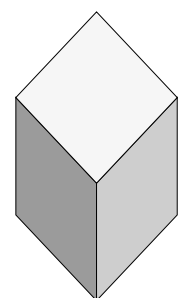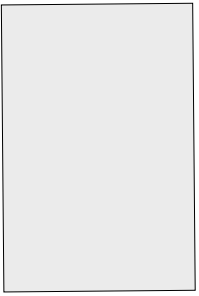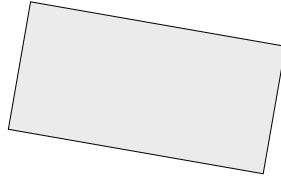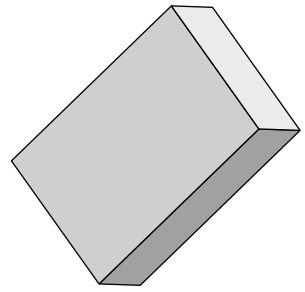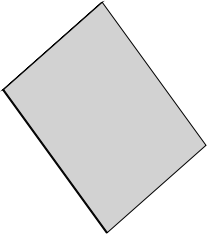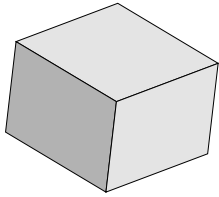
B
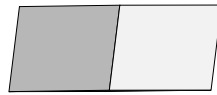
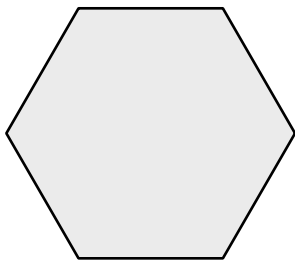**C**
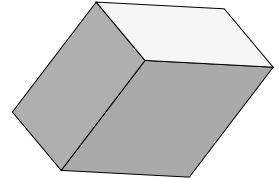
D
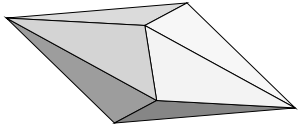
A
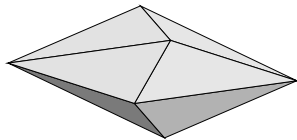
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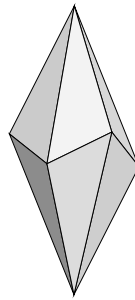
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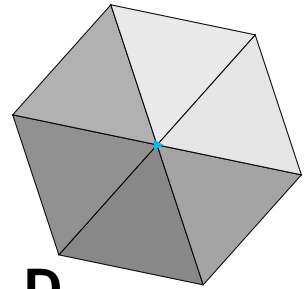
D
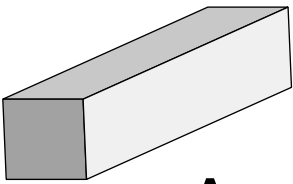
A

B
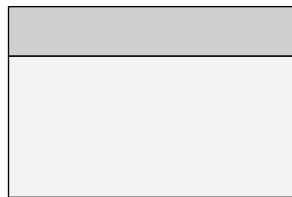
C
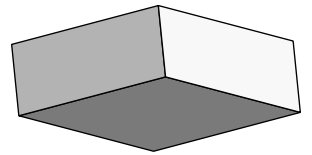
D
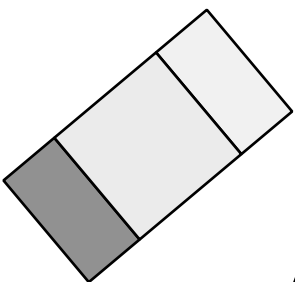
A

B

C

D
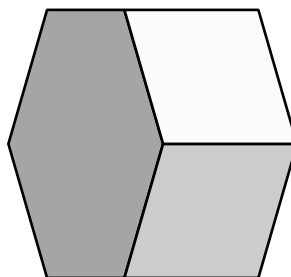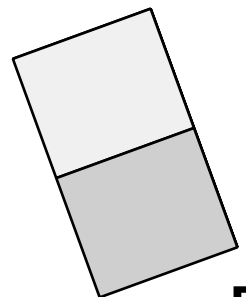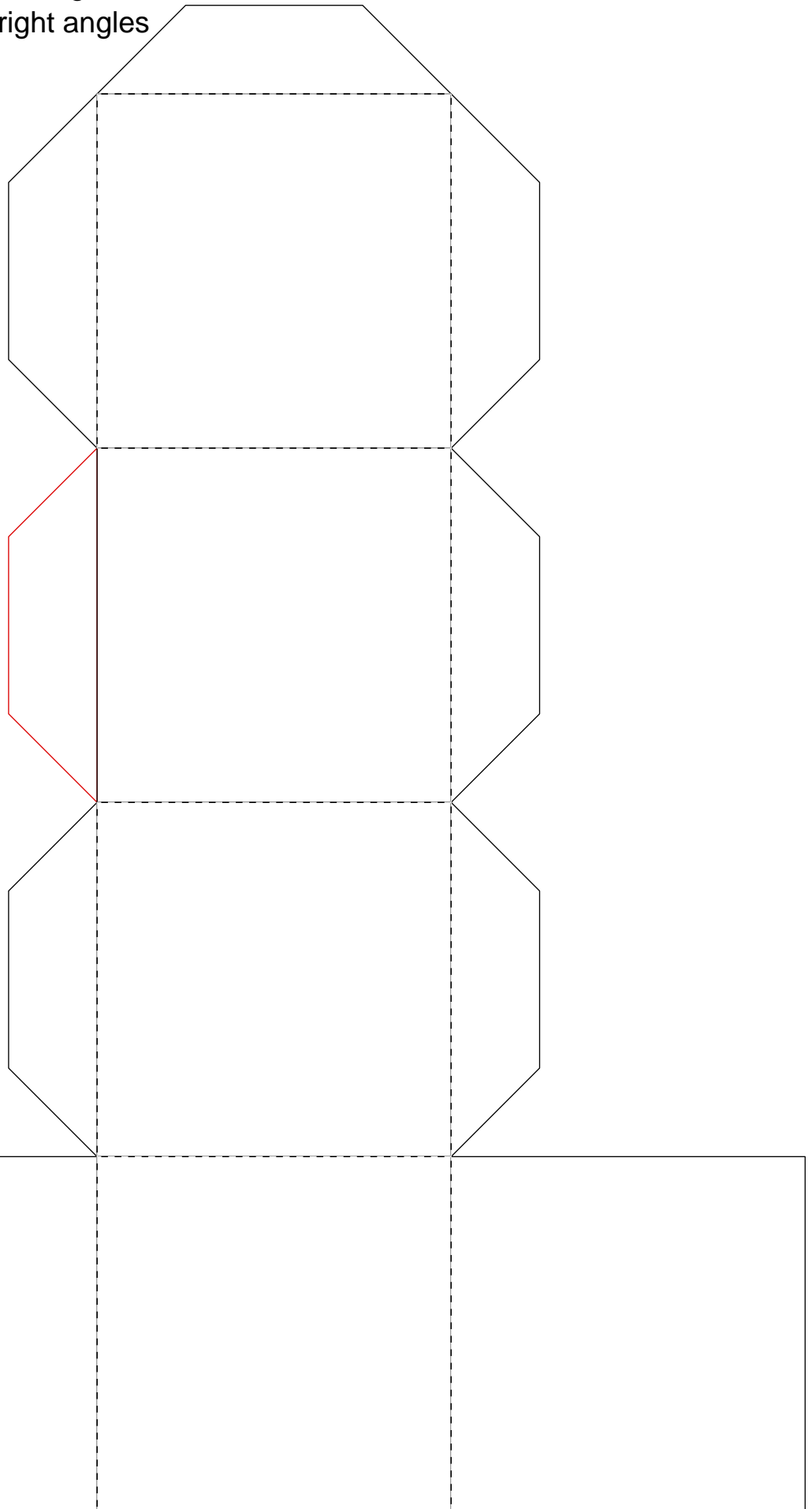
Isometric Cube

all faces have sides of equal length
3 4-fold symmetry axes at right angles
4 3-fold symmetry axes
6 2-fold symmetry axes

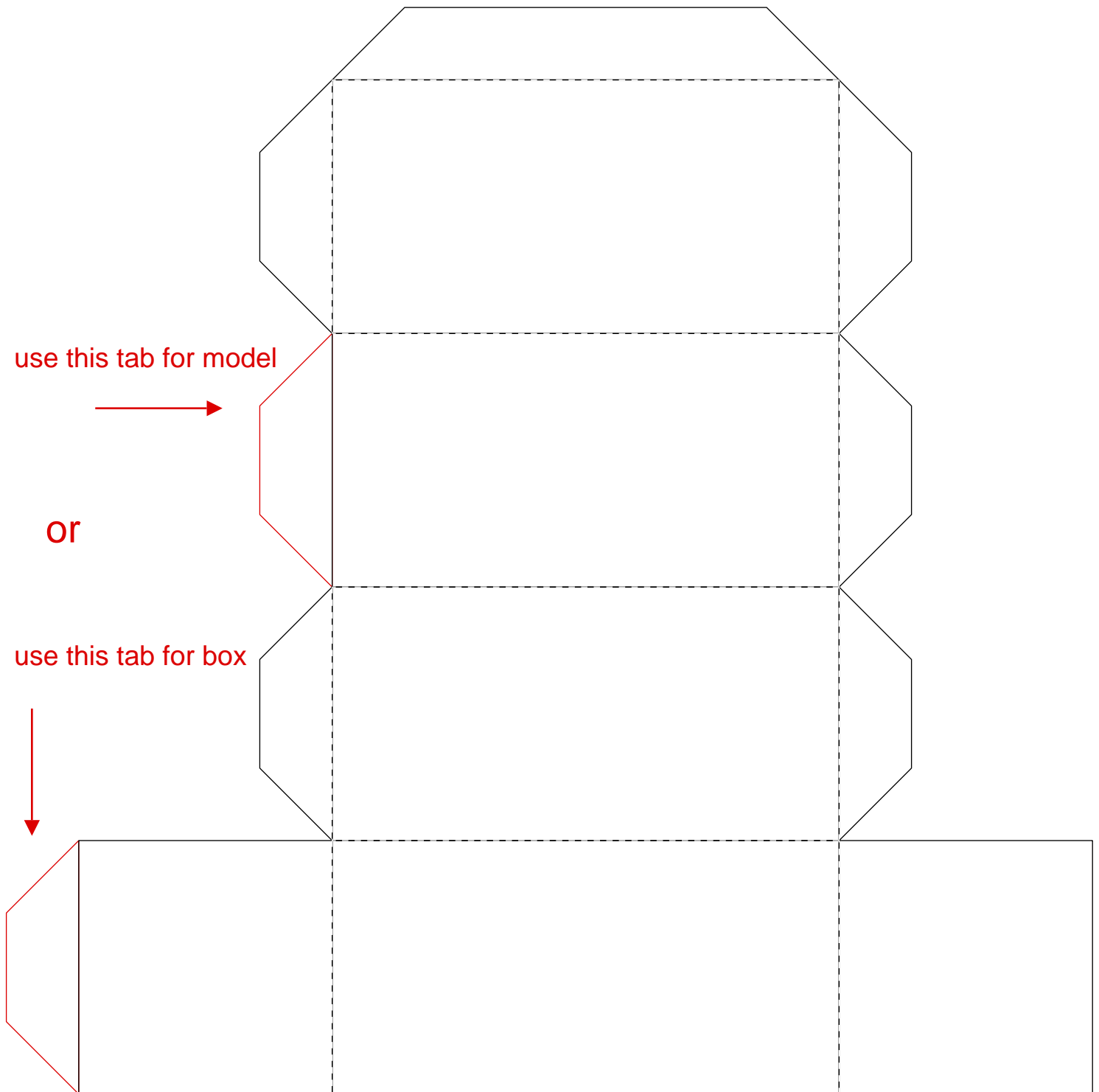use this tab for model

or

use this tab for box

Tetragonal

two faces are squares; the others are identical rectangles
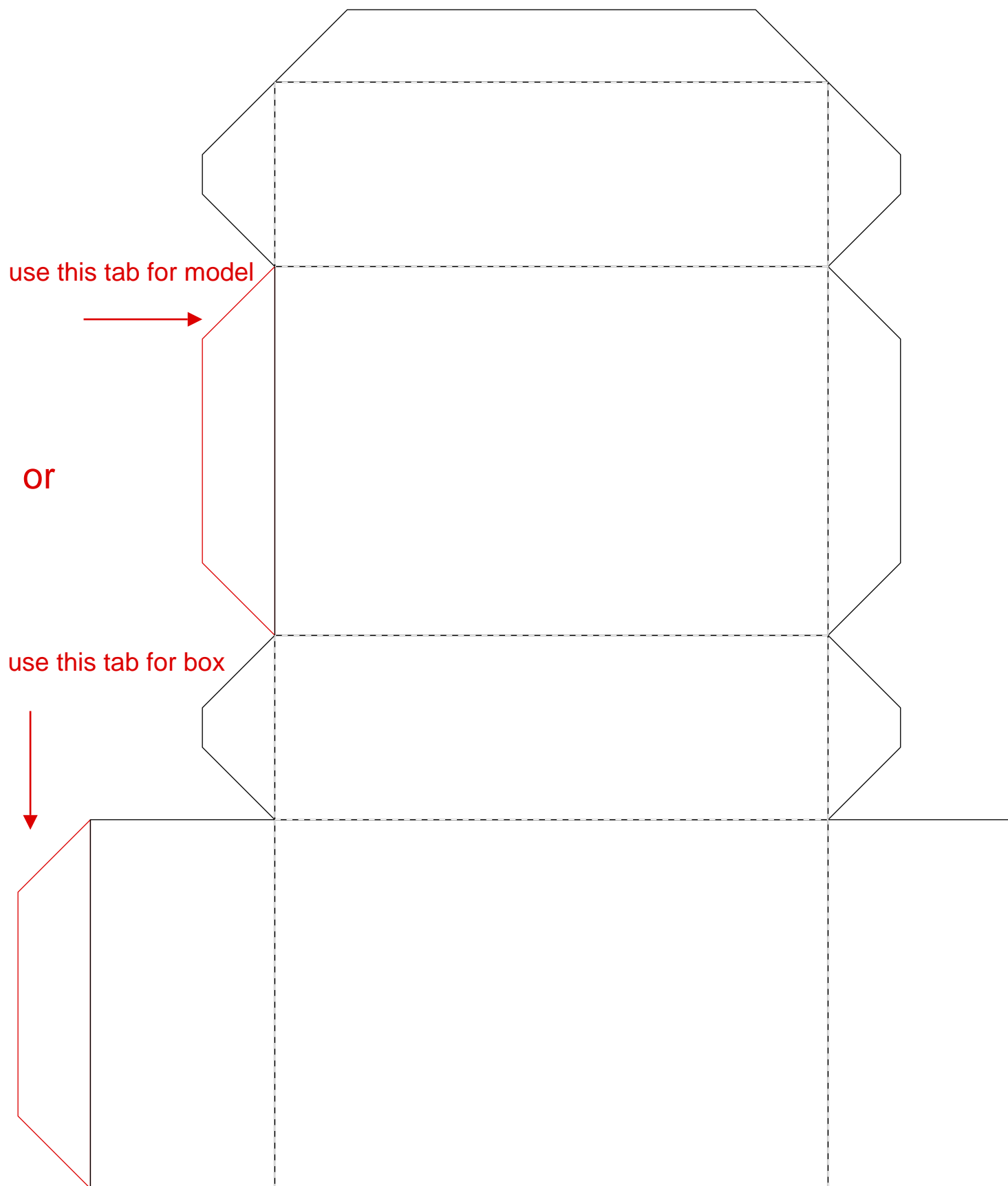
1 4-fold symmetry axis through the square faces

4 2-fold symmetry axes at right angles to it

use this tab for model

or

use this tab for box

Orthorhombic

the sides of the faces are different lengths

3 2-fold symmetry axes at right angles

use this tab for model

or

use this tab for box

Trigonal

all faces have sides of equal length

3 2-fold symmetry axes at 120°
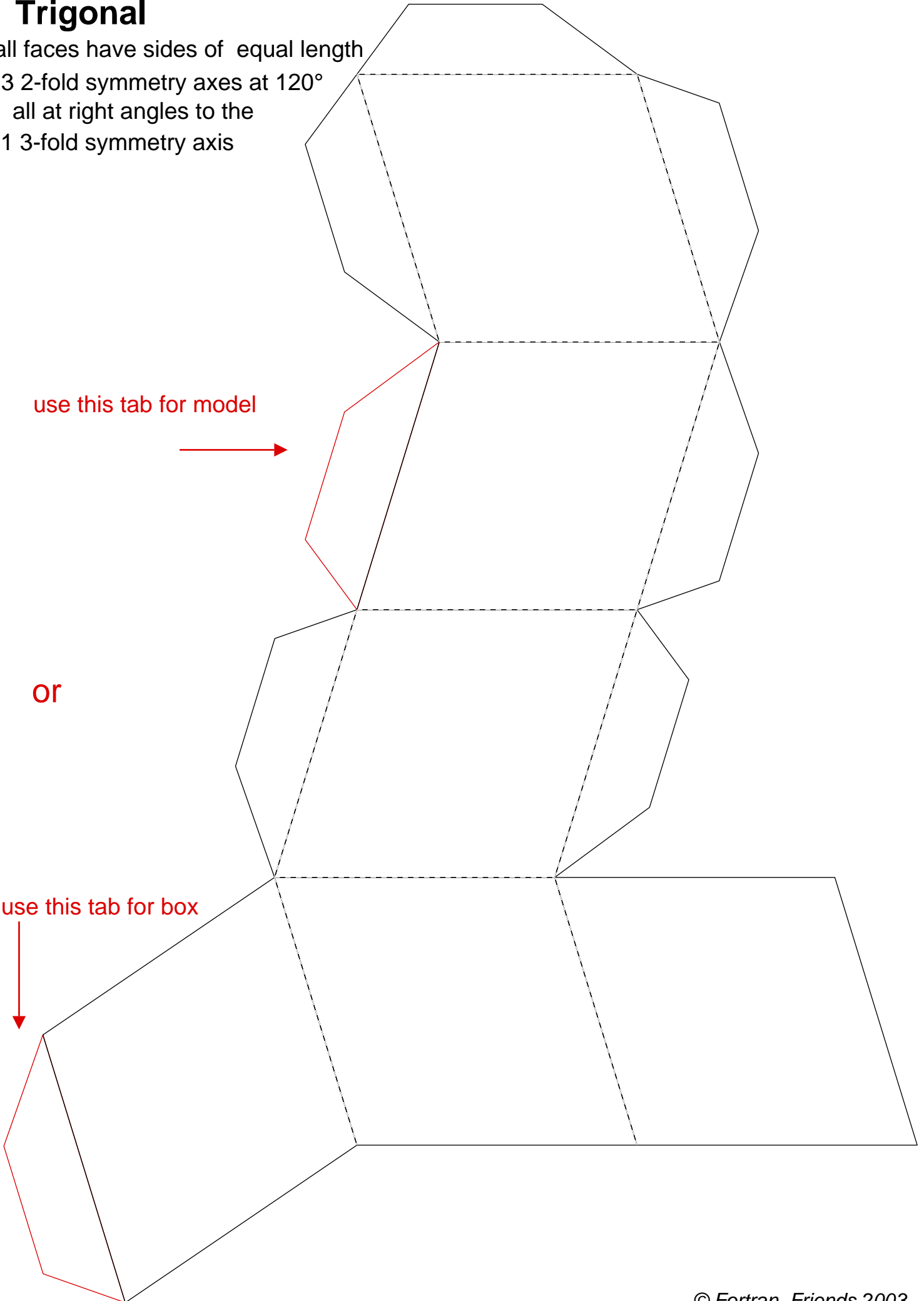all at right angles to the
1 3-fold symmetry axis

use this tab for model
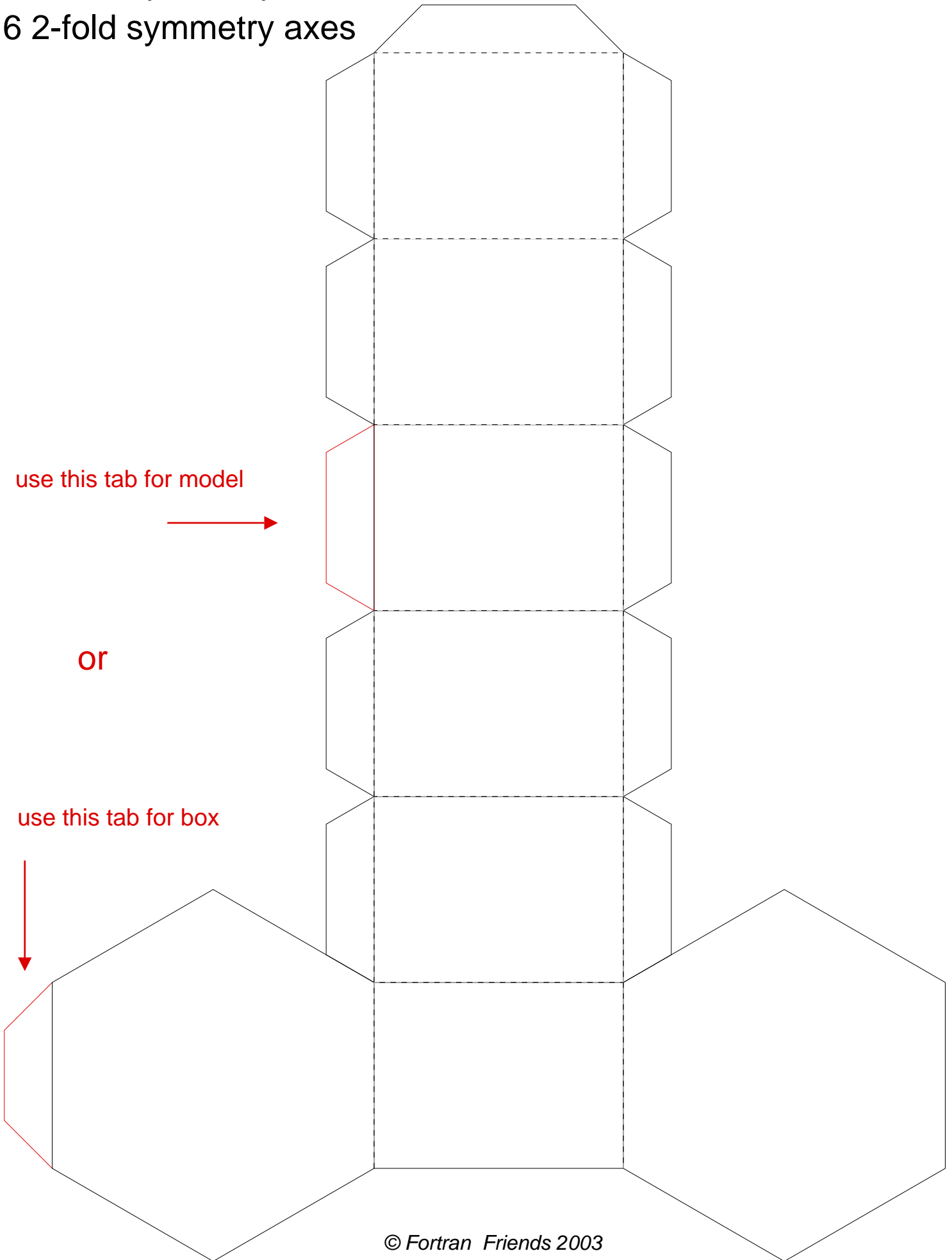
or

use this tab for box

Hexagonal prism

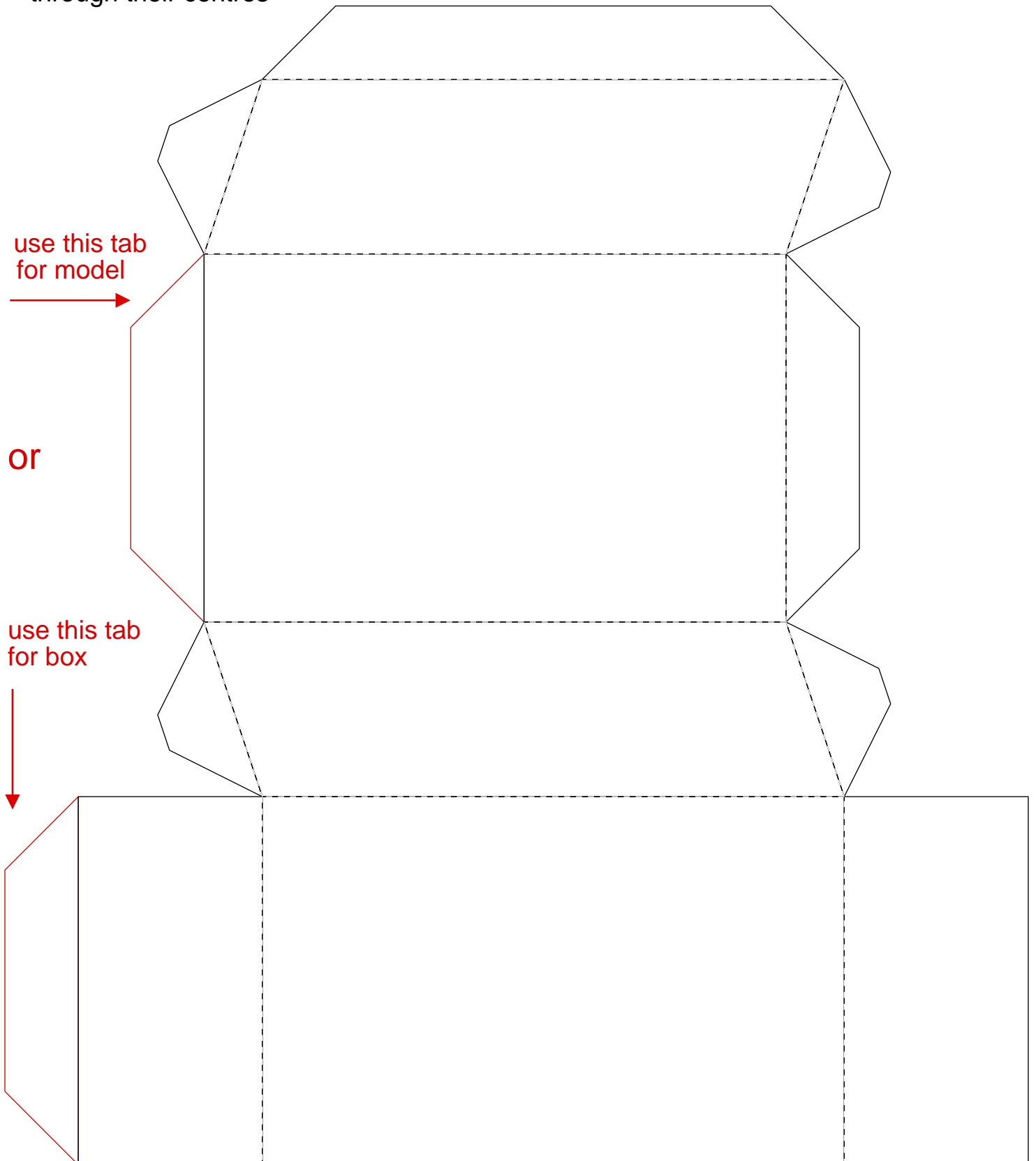## 1 6-fold symmetry axis
6 2-fold symmetry axes

2 regular hexagonal faces
6 identical retangular faces

use this tab for model

or

use this tab for box

Monoclinic

all faces have sides of different lengths
   4 are rectangles
   2 are parallelograms with the
   1 2-fold symmetry axis
   through their centres

use this tab
for model

or

use this tab
for box

Triclinic

3 unequal axes
all inclined at angles
which are not 90°

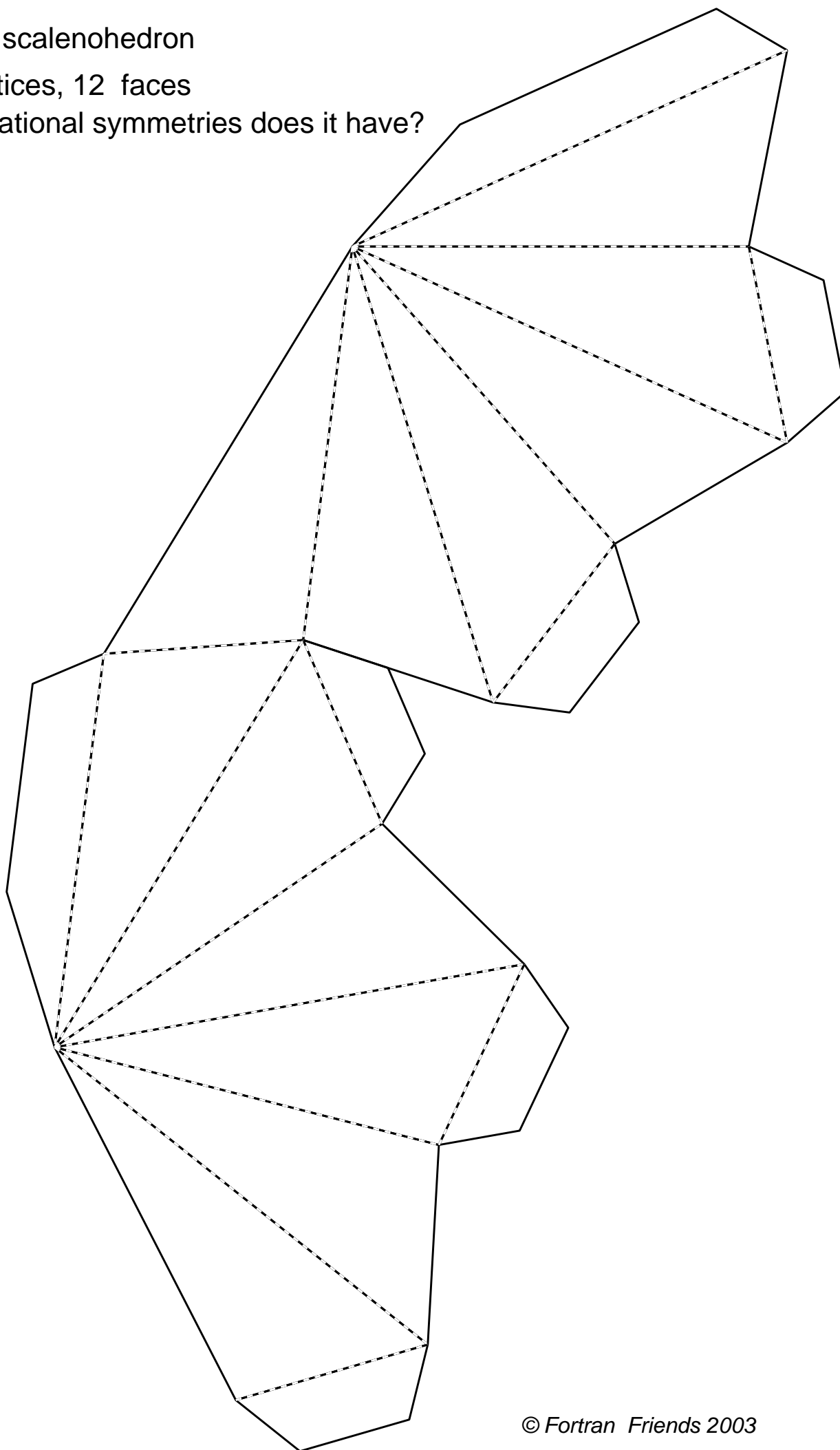use this tab for model

or

use this tab for box

© Fortran Friends 2003
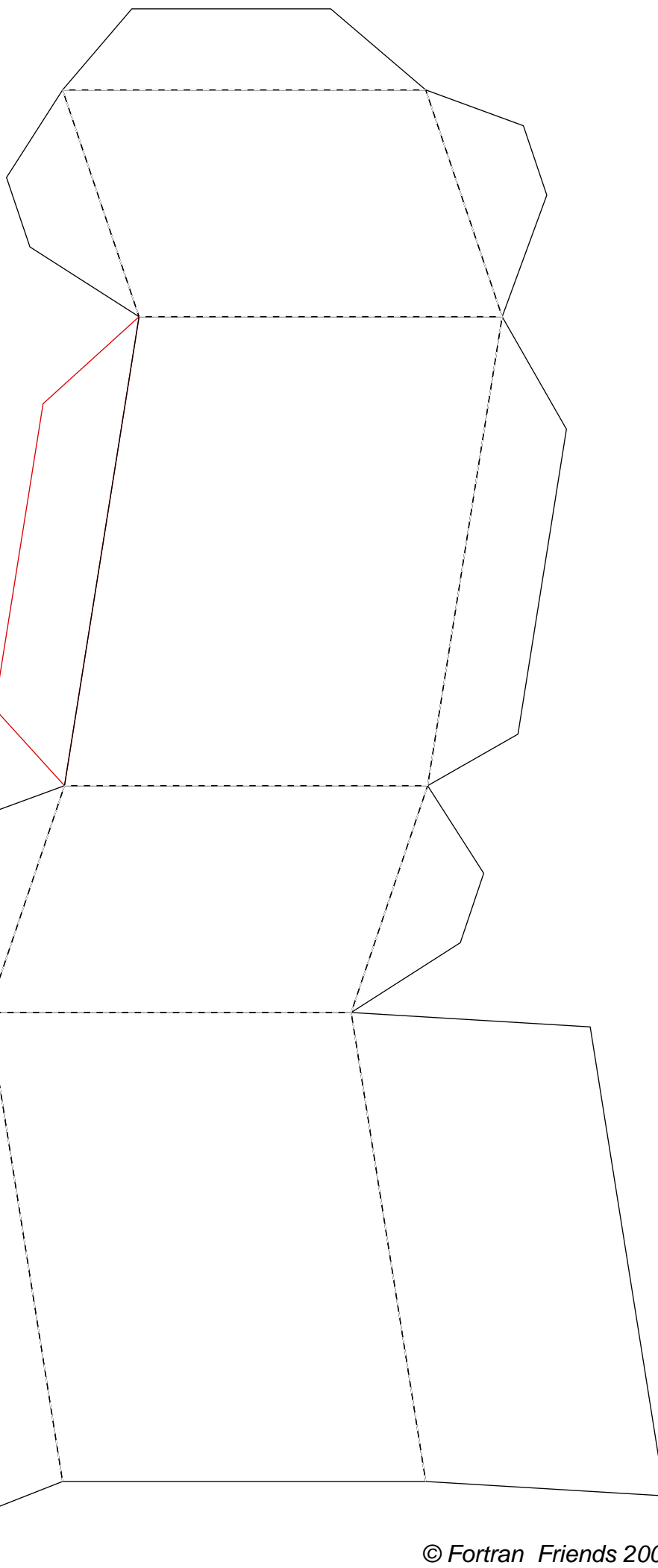
Calcite scalenohedron

8 vertices, 12 faces

What rotational symmetries does it have?

Answers to the Exercises on Pages 4 and 5

The Table below lists the rotational (or reflectional) symmetries for the views in each row.
A view point not looking down and axis of symmetry is labelled 0.
Reflectional symmetries have the letter 'm'.

Page no	Row no	name	A	B	C	D
4	1	cubic	2	4	3	0
4	2	trigonal	3	2	0	m
4	3	tetragonal	0	4	2	0
5	4	orthorhombic	2	2	2	0
5	5	monoclinic	0	2	m	0
5	6	scalenohedron	2	2	0	3
5	7	triclinic	0	0	0	0
5	8	hexagonal	0	6	0	2