Hashemite University

Faculty of Natural Resources and Environment

Department of earth and environmental sciences

Mineralogy (1201220)

Chapter 5: Crystallography

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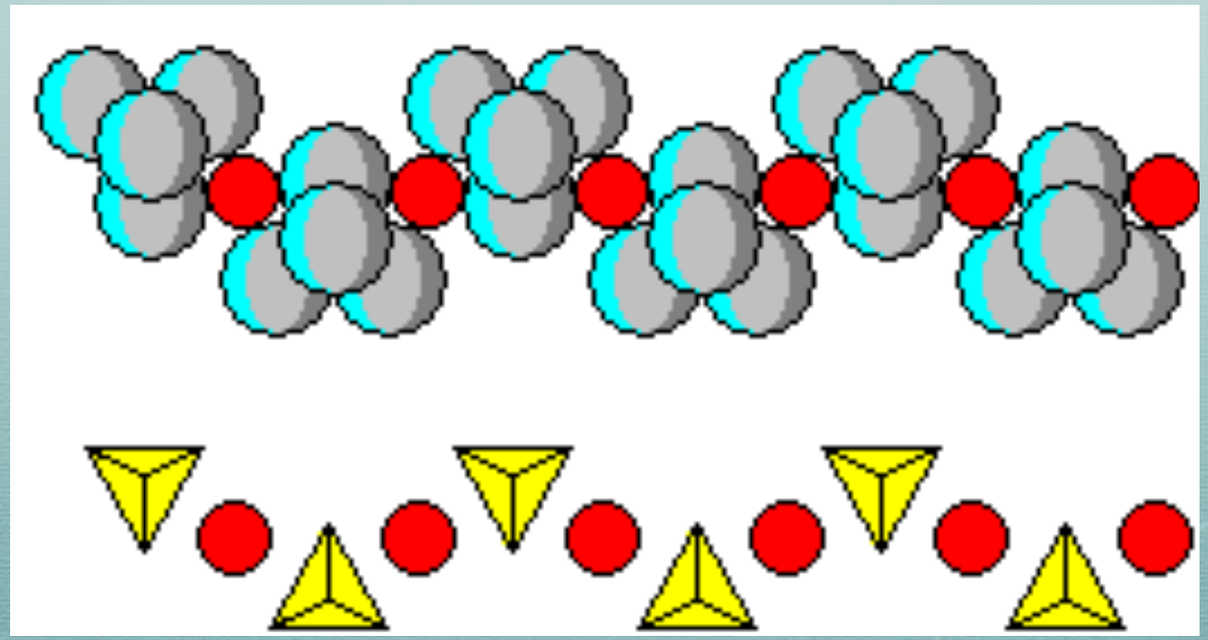
First Semester 2015/2016



Crystallography

Science study the crystalline solids and the principles that govern their growth, external shape (Geometry), and internal structure.

A crystal is a solid object with a geometric shape that reflects a regular internal structure.

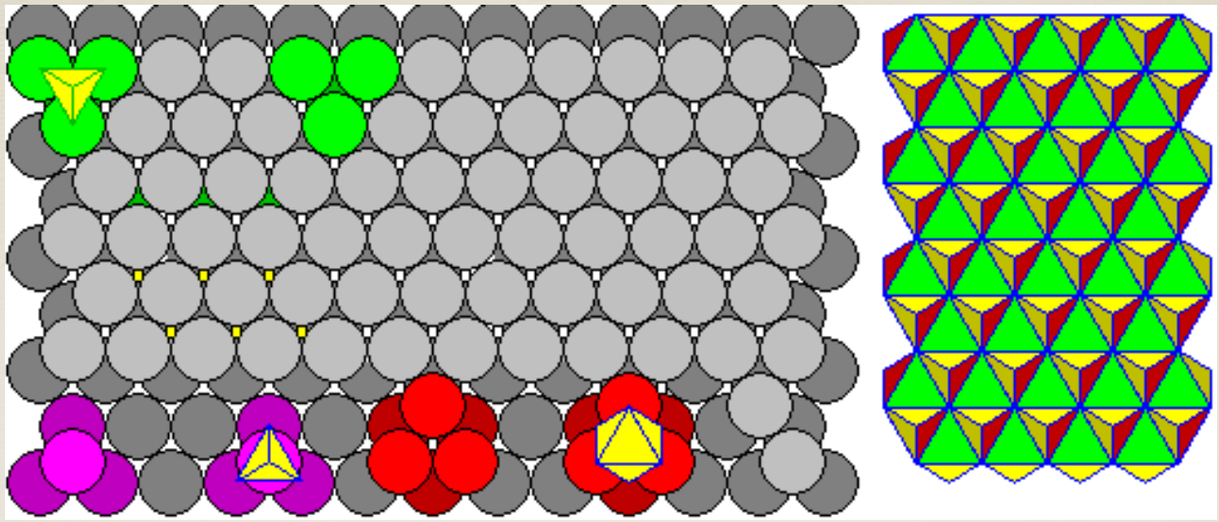
Crystallization Processes

- different media (liquid, solid, gas) have ions in random case
- change in conditions needed (T,P,X)
- repetition of unit (atoms, anionic group, molecules, ions, combination) in 3D must be

Very slow cooling of a liquid allows atoms to arrange themselves into an ordered pattern, which may extend of a long range (millions of atoms).

This kind of solid is called crystalline.

Space lattices: is "a 3_Dimensional array of points in space that can be repeated indefinitely".

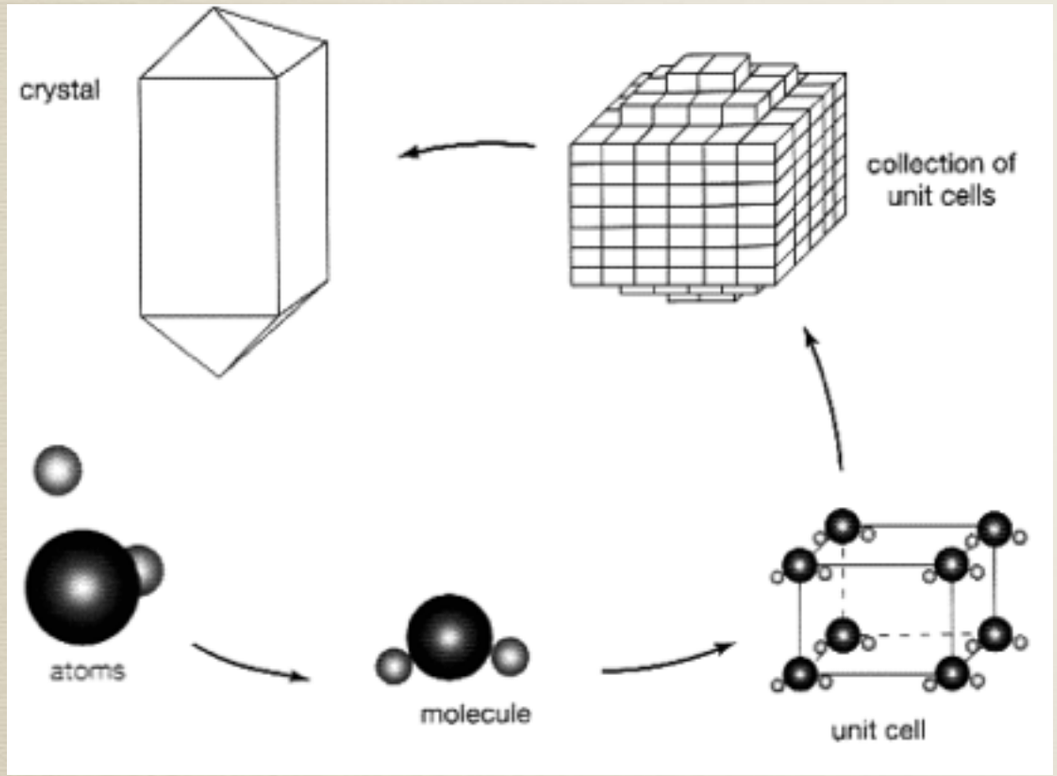


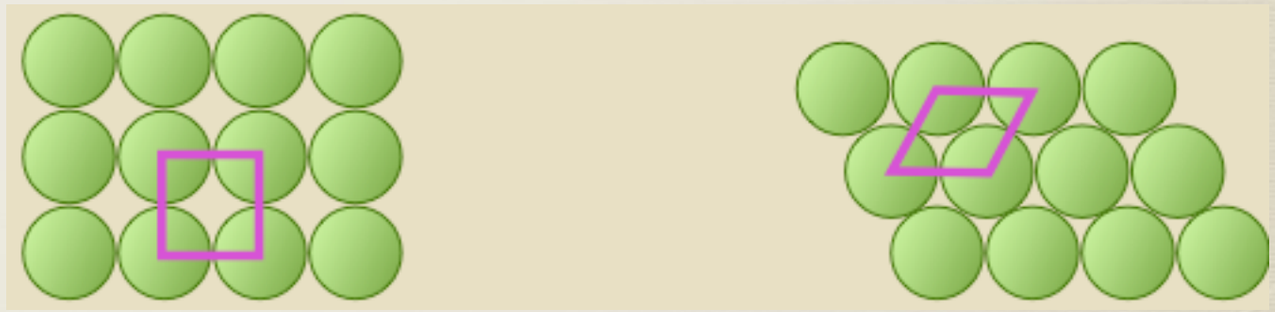
- All "points" in a lattice have identical environments these "points"known as **motifs** or **unit cells** may be considered atoms, ions, or groups of atoms/ ions.

- The repetition of those unit cells in a space lattice is performed by certain **operations** which build the space lattice.

Building a space lattice: from motifs to lattices:

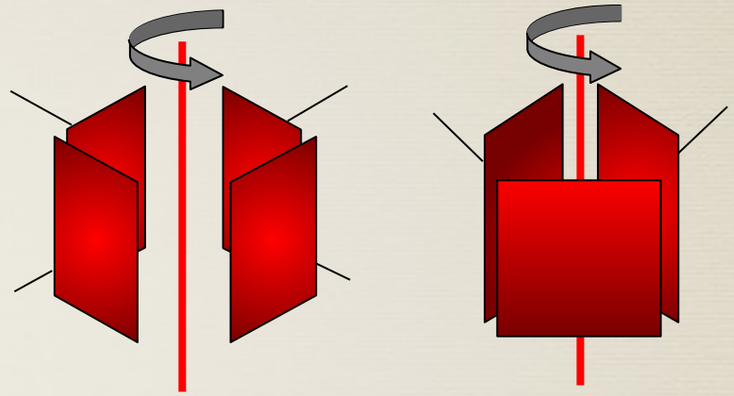
Motif → Line lattice → Plane lattice → Space Lattice





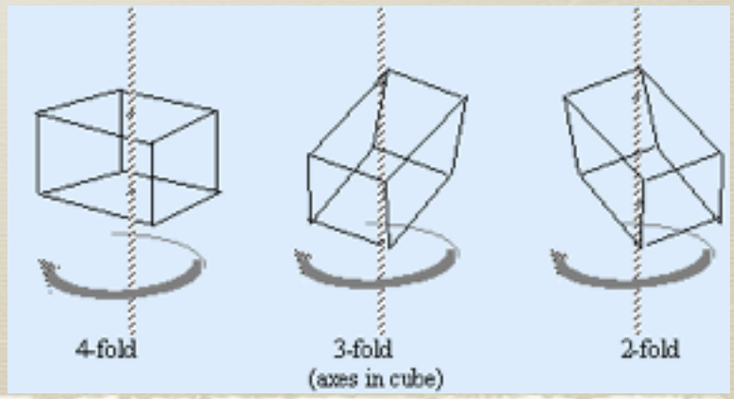
Elements of symmetry:

i– Axes of rotation (1, 2, 3, 4 or 6): If during the rotation of a crystal around an axis one of the faces repeats itself two or more times, the crystal is said to have an axis of symmetry.

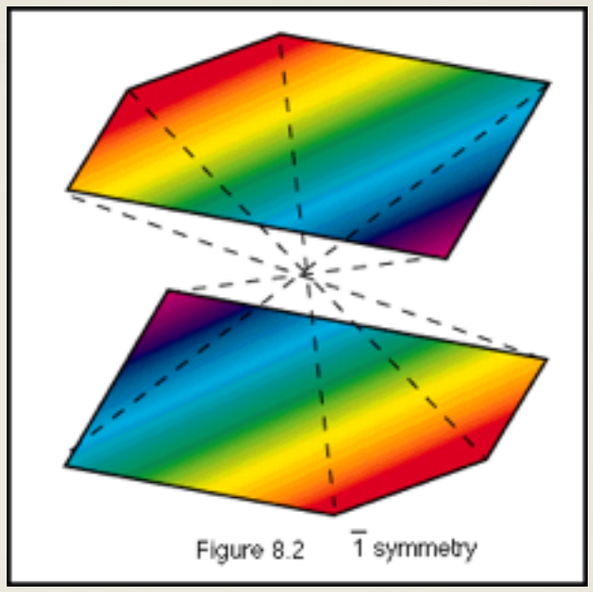


Symmetry axes may be

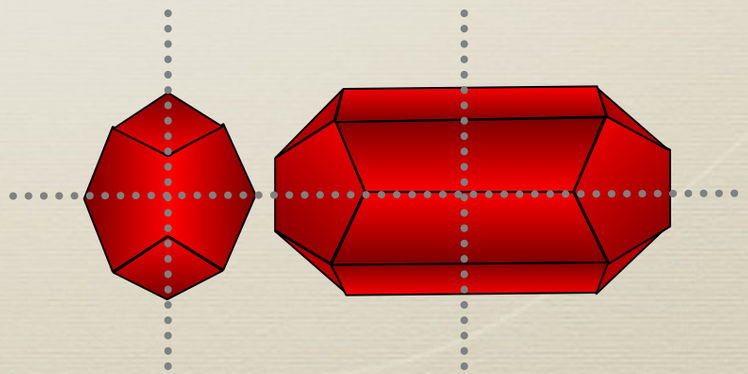
- two fold (digonal) if a face is repeated twice every 360°,
- three fold (trigonal) if it is repeated three times,
- four fold (tetragonal) if it is repeated four times, or
- six fold (hexagonal) if that face is repeated 6 times.



ii- Center (n or i): If two similar faces lie at equal distances from a central point, the crystal is said to have a centre of symmetry.



iii- Planes (m): When one or more faces are the mirror images of each other, the crystal is said to have a plane of symmetry.



Crystal Morphology

Crystal Faces: the regular internal structure of a mineral is manifested by the development of surfaces that define the shape of the crystal, and which may be related to one another by certain elements of symmetry.

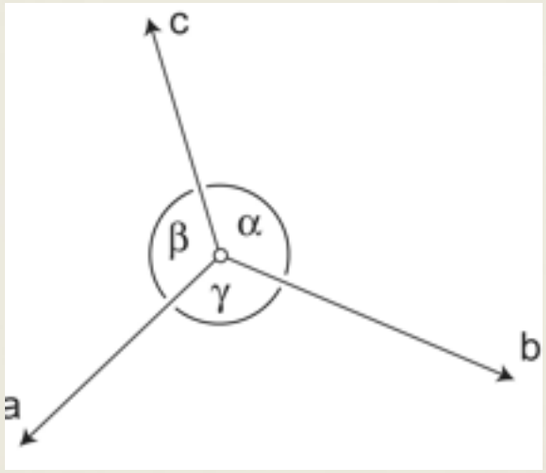
- **Bravais Law**: states that the frequency by which a face is observed in a crystal is directly proportional to the number of "points" it intersects in a lattice.

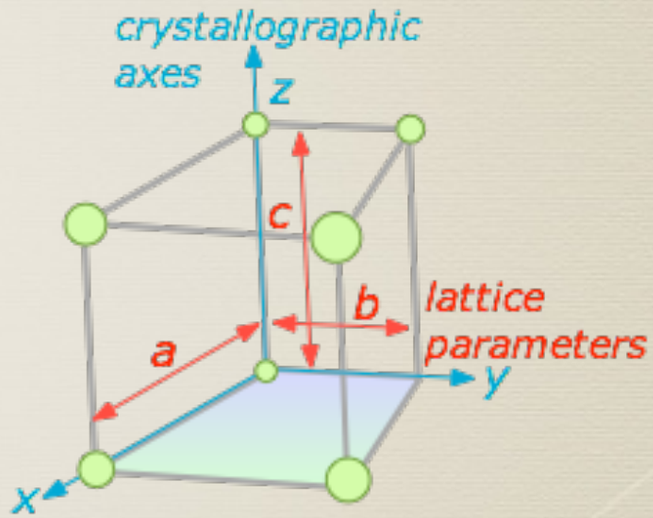
- **Factors affecting the morphology of a crystal (conditions of growth):**

1. T
2. P
3. solutions available
4. direction of solution flow
5. availability of open space.

- **Steno's Law**: The angles between these faces (known as the **interfacial angles**) are always constant for the same mineral (at the same temperature).

Crystallographic axes are imaginary lines of reference inside a crystal that intersect at a crystal centre. Any crystal has either 3 or 4 crystallographic axes (a, b and c or a1,a2,a3,c). The angles between these axes are known as the **interaxial angles** (alpha, beta and gama).





Crystal Forms:

Two or more faces having the same geometric relations to the crystallographic axes, and the same shape, and which are related to each other by some element of symmetry in a crystal.

The Crystal Systems

The crystal classes are grouped into seven crystal systems based on the following criteria:

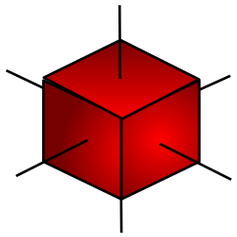
a) relative lengths of the crystallographic axes

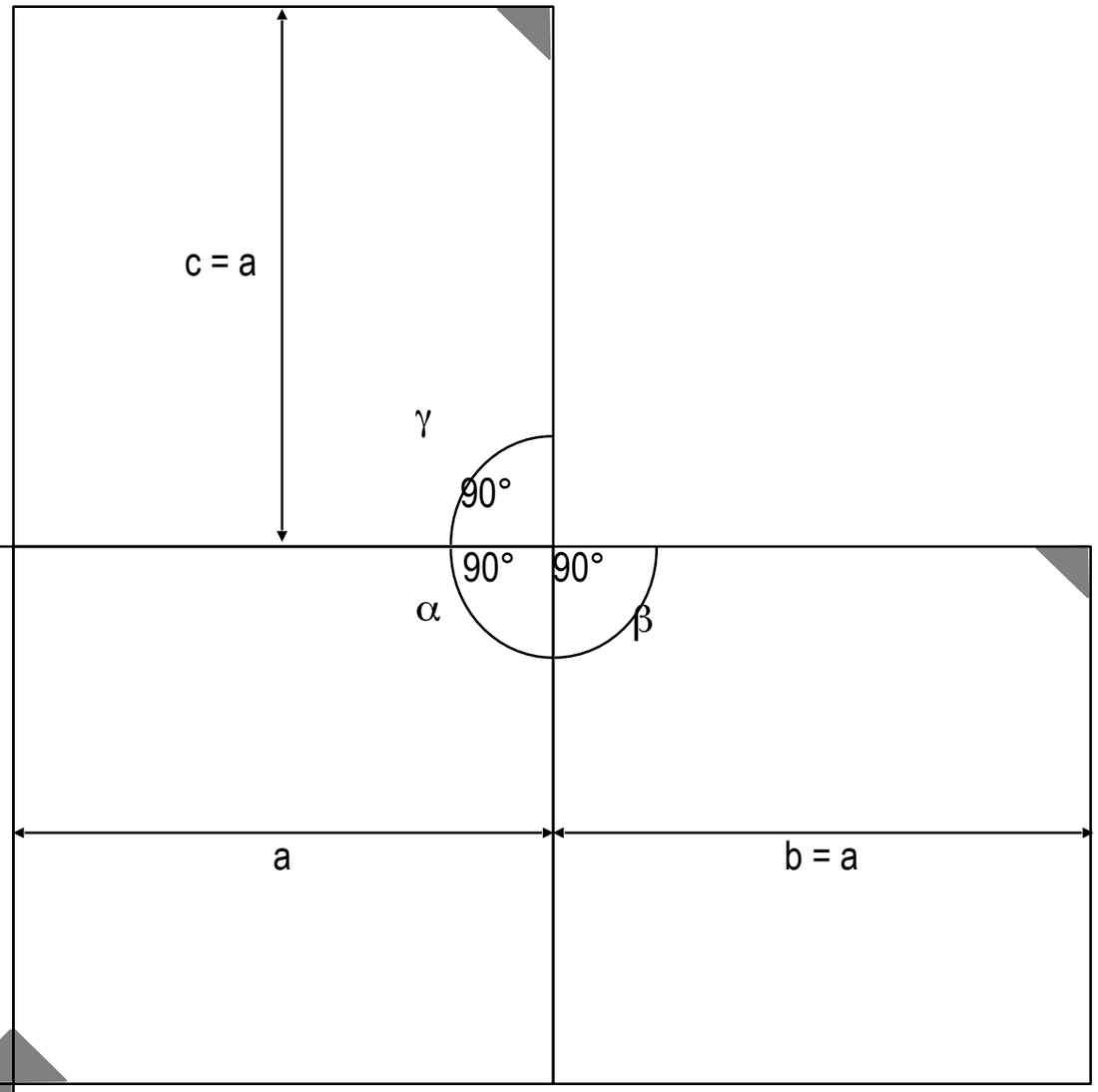
b) number of crystallographic axes

c) values of the interaxial angles

d) some essential element of symmetry

Isometric System





Pyrite, Galena,

Halite, Fluorite,

Garnet, Diamond

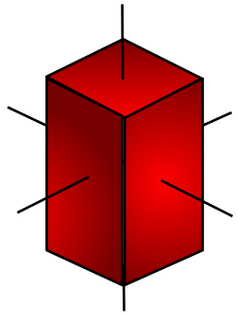
ISOMETRIC

$\alpha = \beta = \gamma = 90°$

a = b = c

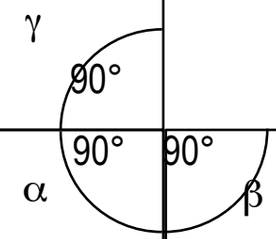
Unique Symmetry:
Four 3-fold axes

Tetragonal System



Wulfenite, Zircon,

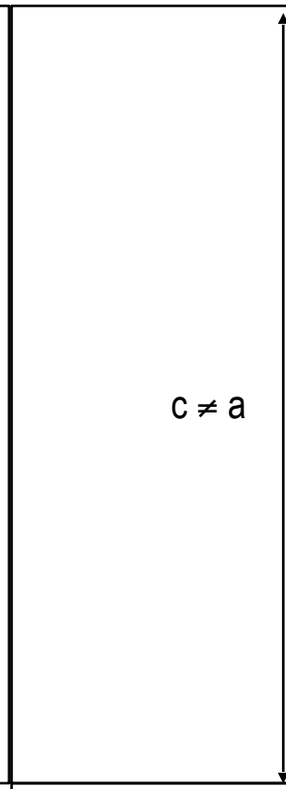
Chalcopyrite, Rutile

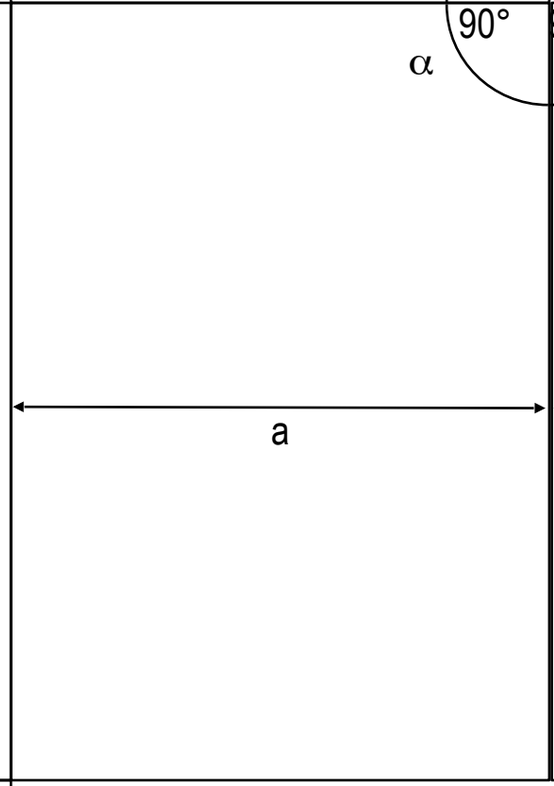


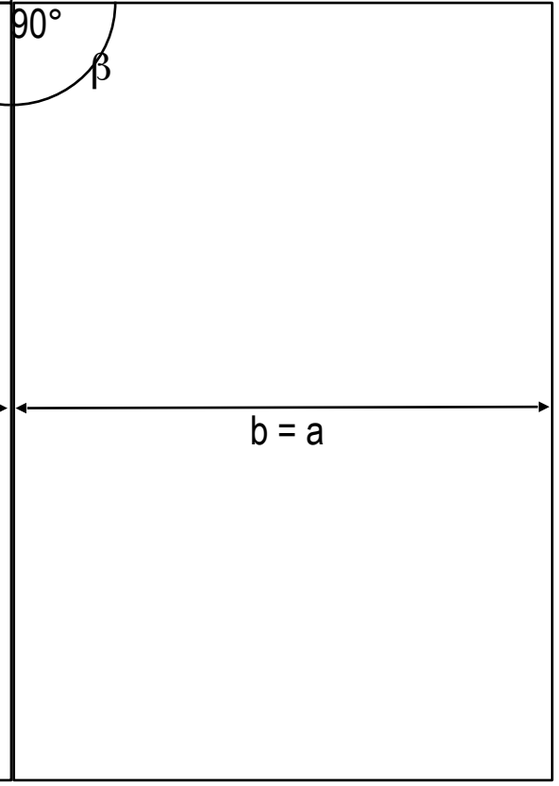
TETRAGONAL

$\alpha = \beta = \gamma = 90°$

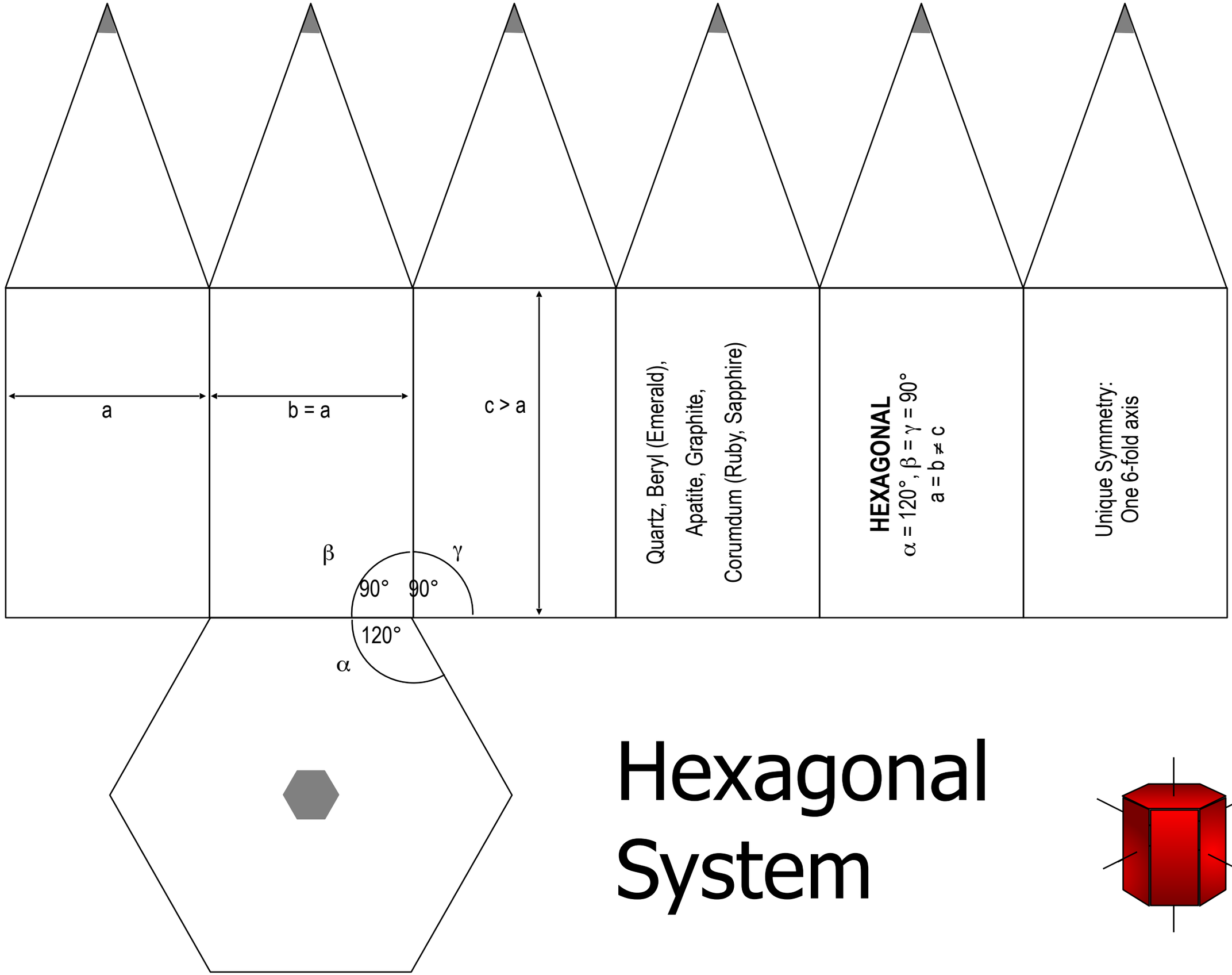
$a = b \neq c$





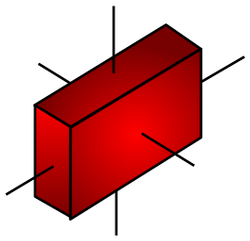


Unique Symmetry:
One 4-fold axis



Hexagonal System

Orthorhombic System



Sulfur, Barite,

Olivine, Topaz

γ

90°

90° 90°

α β

ORTHORHOMBIC

$\alpha = \beta = \gamma = 90°$

$a \neq b \neq c$

$c \neq a$

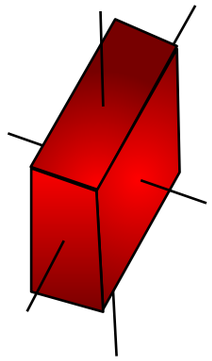
a

$b \neq a$

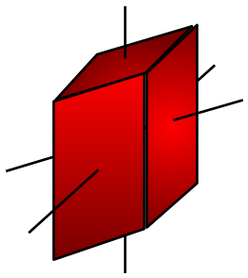
Unique Symmetry:

Three 2-fold axes

Monoclinic System



Triclinic System



Unique Symmetry:
None

$a \neq c$

$\alpha \neq 90°$

$\beta \neq 90°$

$\gamma \neq 90°$

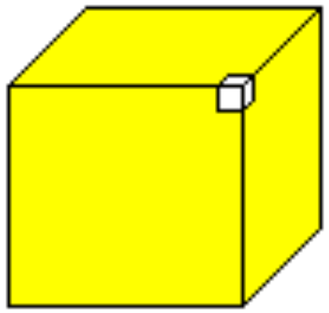
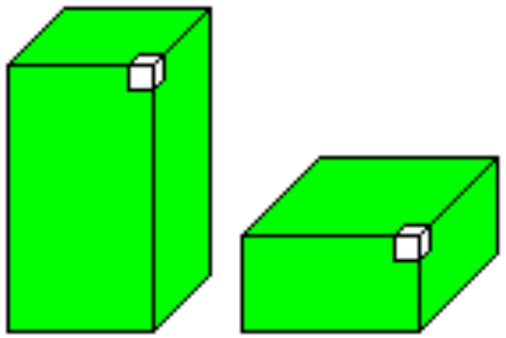
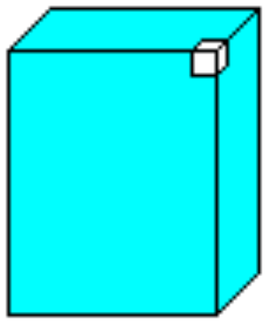
$b \neq a$

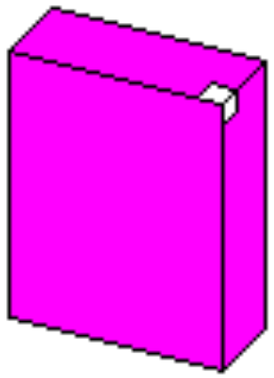
TRICLINIC

$\alpha \neq \beta \neq \gamma \neq 90°$

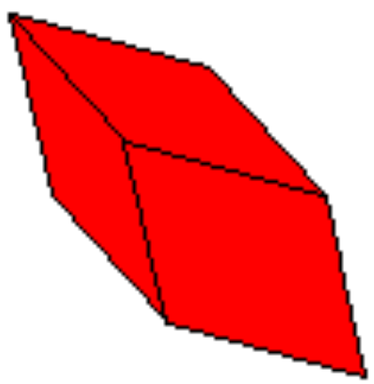
$a \neq b \neq c$

Turquoise, Plagioclase
Kyanite, Albite

Cubic (Isometric) 	ISOMETRIC or CUBIC All edges equal, all angles 90 degrees Halite, Fluorite, Pyrite Galena, Garnet, Magnetite Gold, Copper, Diamond
Tetragonal 	TETRAGONAL Two edges equal, all angles 90 degrees. Square cross-section but different third dimension. Zircon Chalcopyrite
Orthorhombic 	ORTHORHOMBIC No edges equal, all angles 90 degrees. Like the shape of a cereal carton. Olivine, Andalusite, Sillimanite Some Amphiboles and Pyroxenes Topaz, Sulfur

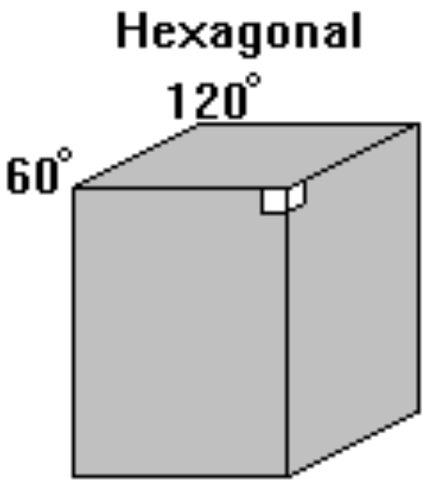


MONOCLINIC
No edges equal, two angles 90 degrees. The shape obtained by knocking the ends out of a carton and skewing it.
Some Amphiboles and Pyroxenes
Micas
Gypsum, Epidote
Sugar also belongs to this crystal class.



TRICLINIC
No edges equal, no angles 90 degrees
Most Feldspars
Kyanite
Clay Minerals

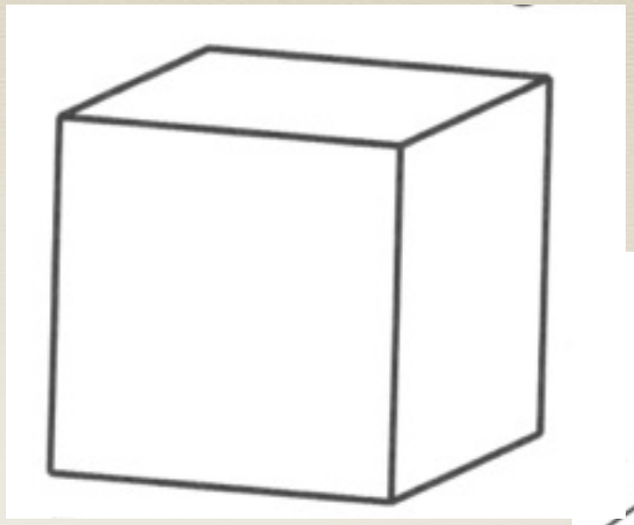
What if you have one 90 degree angle, or two equal edges? It turns out that these contribute no extra symmetry and the crystal is still triclinic.

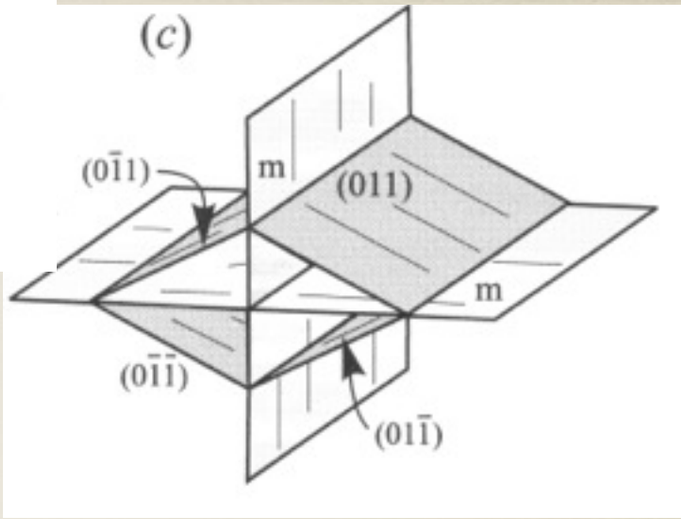


HEXAGONAL
Angles of 60, 90, and 120 degrees.
Ice (snowflakes)
Quartz, Beryl
Corundum, Hematite
Calcite, Dolomite

Distribution of minerals among the different crystal systems:

1. 26% cubic,
2. 21% monoclinic,
3. 20% Orthorhombic.



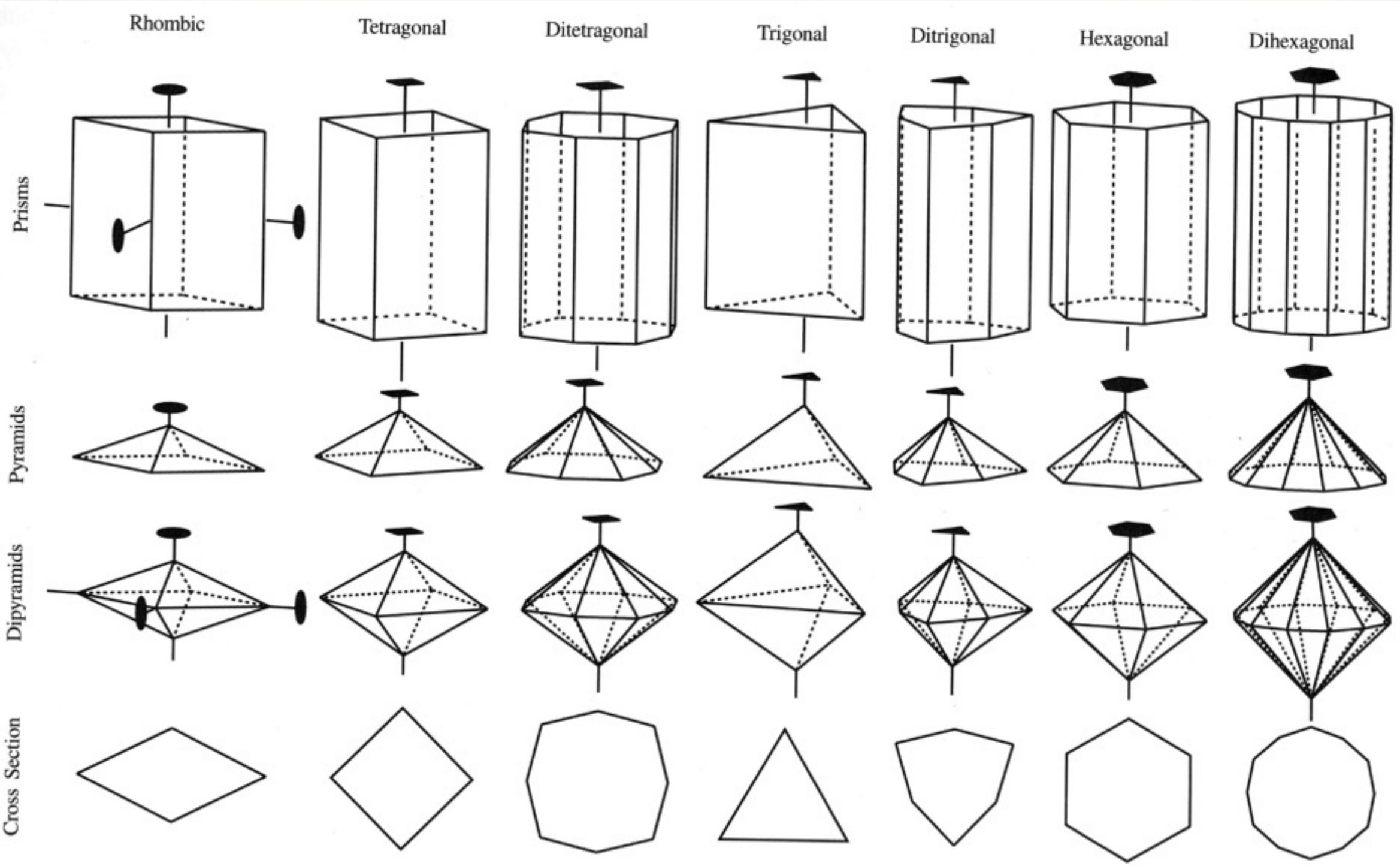


Two types of forms:

- Open form – one or more faces that do not completely enclose space
- Closed form – faces that completely enclose space

There are 32 forms in the **nonisometric** (noncubic) crystal systems and another 15 forms in the **isometric** (cubic) system.

Three types – seven modifiers – total of 21 forms



Isometric Crystal Forms

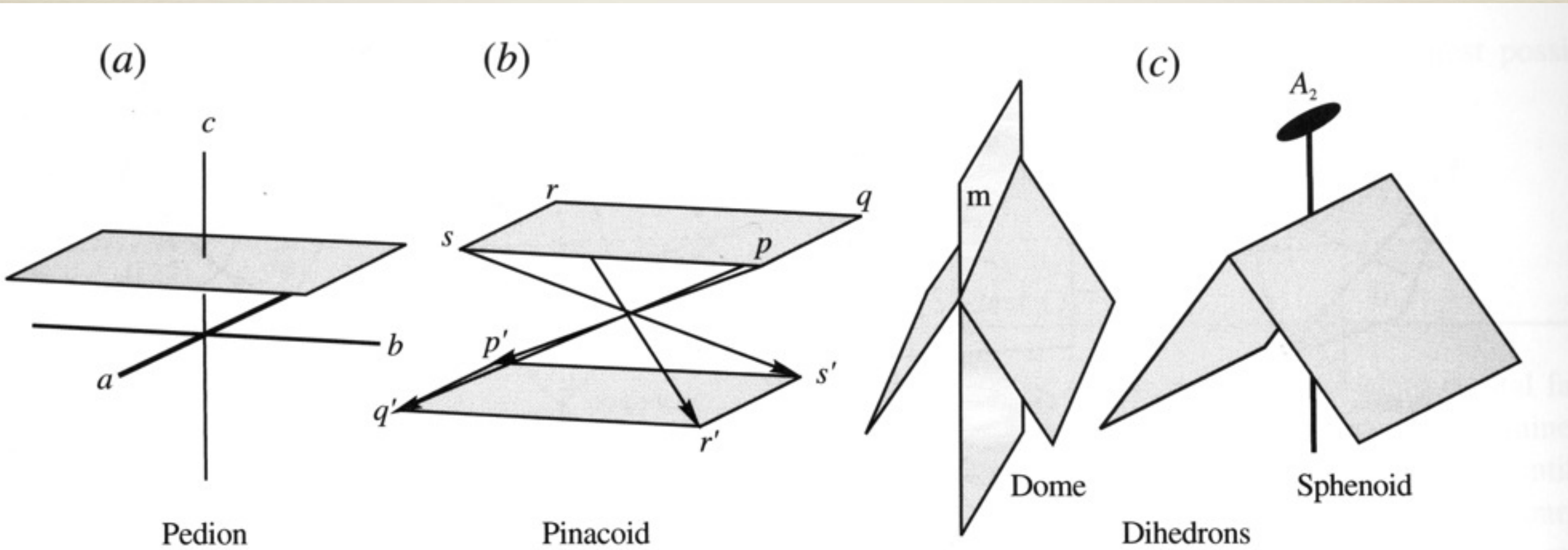
Name	Number of Faces
 (1) Cube	6
 (2) Octahedron	8
 (3) Dodecahedron	12
 (4) Tetrahexahedron	24
 (5) Trapezohedron	24
 (6) Trisoctahedron	24
 (7) Hexoctahedron	48
 (8) Tetrahedron	4

Name	Number of Faces
 9)Tristetrahedron	12
 (10) Hextetrahedron	24
 (11) Deltoid dodecahedron	24
 (12) Gyroid	24
 (13) Pyritohedron	12
 (14) Diploid	24
 (15) Tetartoid	12

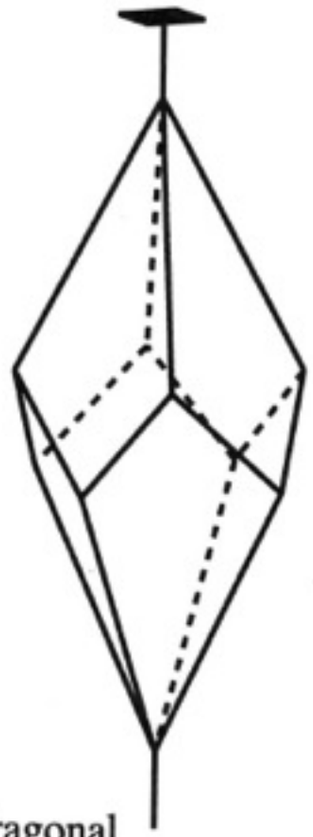
Non-isometric form

10 types of forms

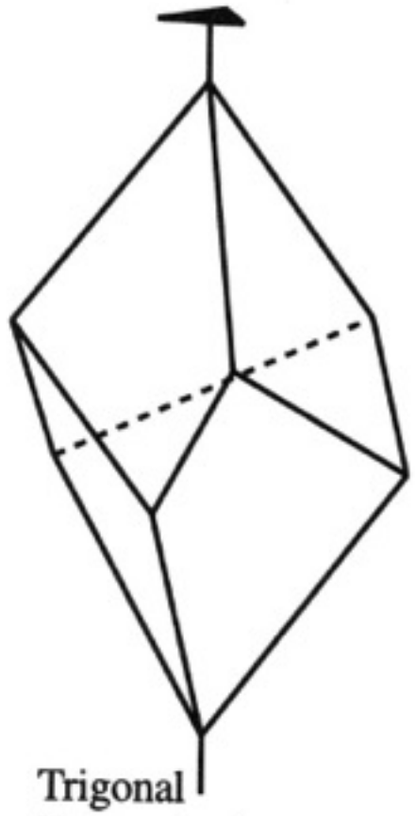
- Pedion (open): Single face
- Pinacoid (open): Two parallel faces
- Dihedron (open): Two non-parallel face



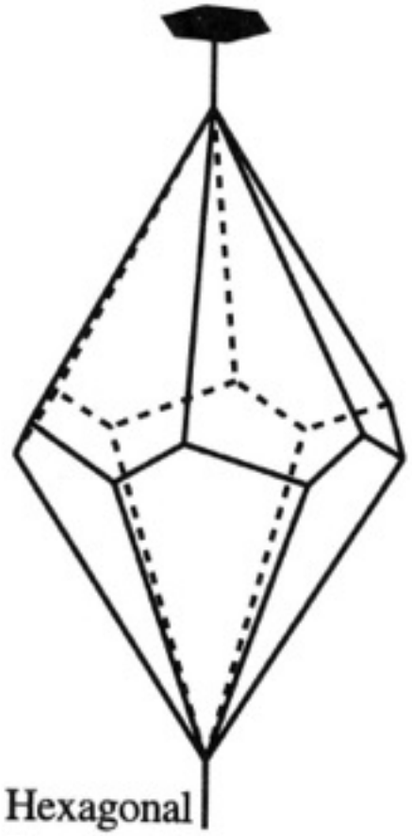
- Trapezohedrons (closed)
  - 6, 8, 12 faces
- Scalenohedron (closed)
  - 8 or 12 faces
  - Each a scalene triangle (no two angles are equal)
- Rhombohedrons (closed)
  - 6 faces, each rhomb shaped (4 equal sides, no 90 angles)
- Tetrahedron (closed)
  - 4 triangular faces



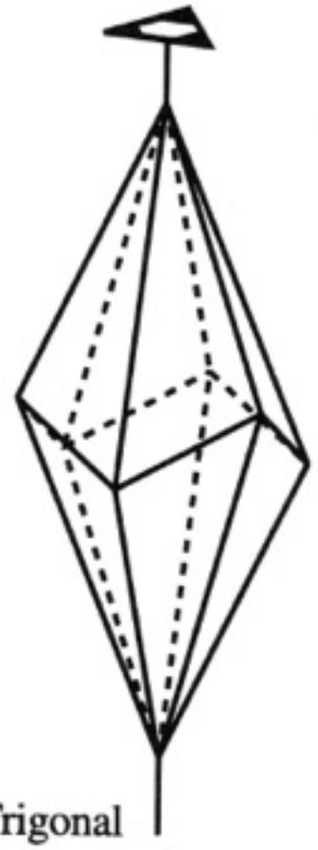
Tetragonal
Trapezohedron



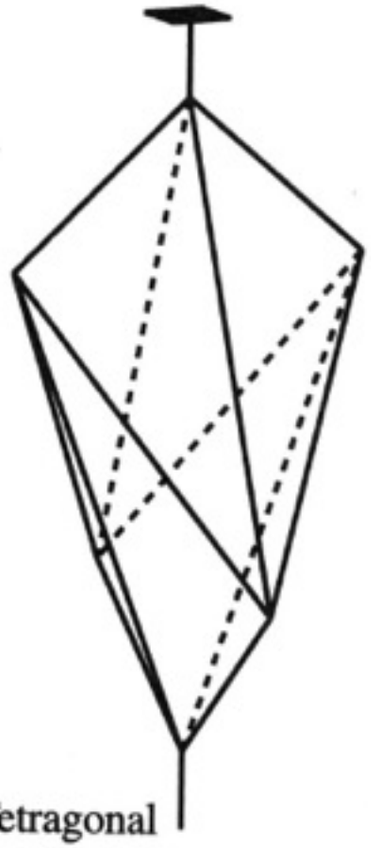
Trigonal
Trapezohedron



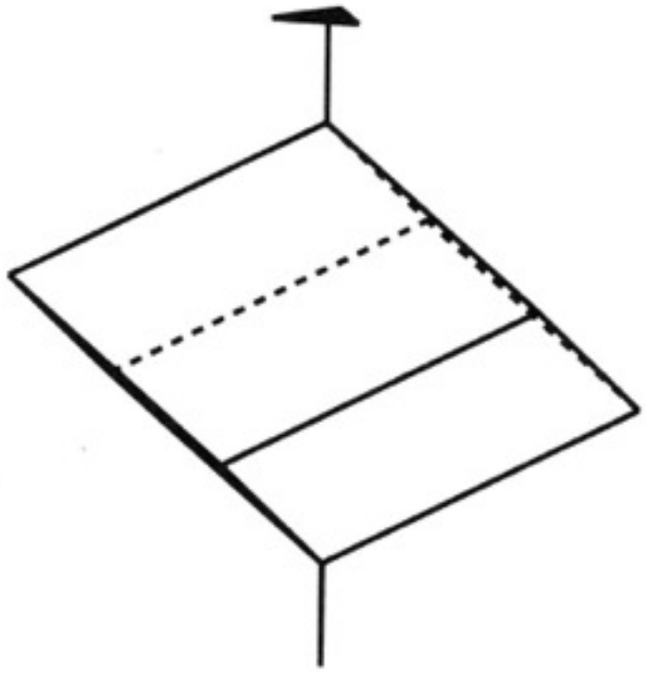
Hexagonal
Trapezohedron



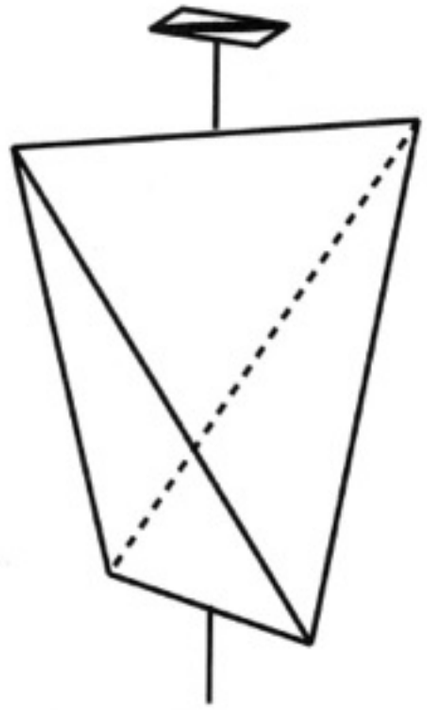
Trigonal
Scalenohedron



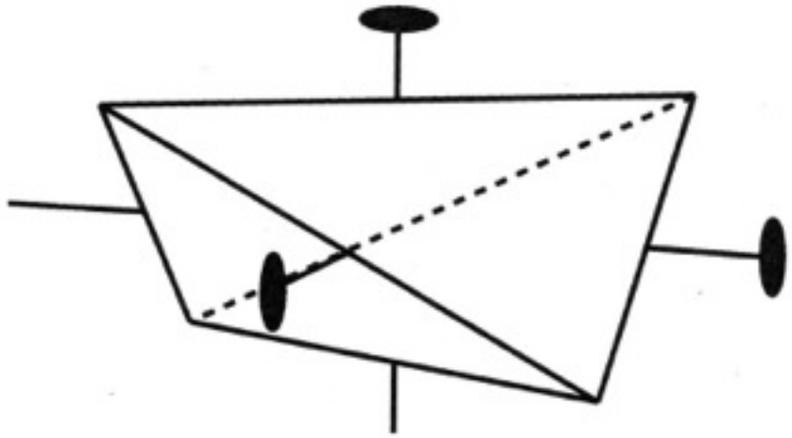
Tetragonal
Scalenohedron



Rhombohedron



Tetragonal Tetrahedron
(Tetragonal Disphenoid)



Rhombic Tetrahedron
(Rhombic Disphenoid)