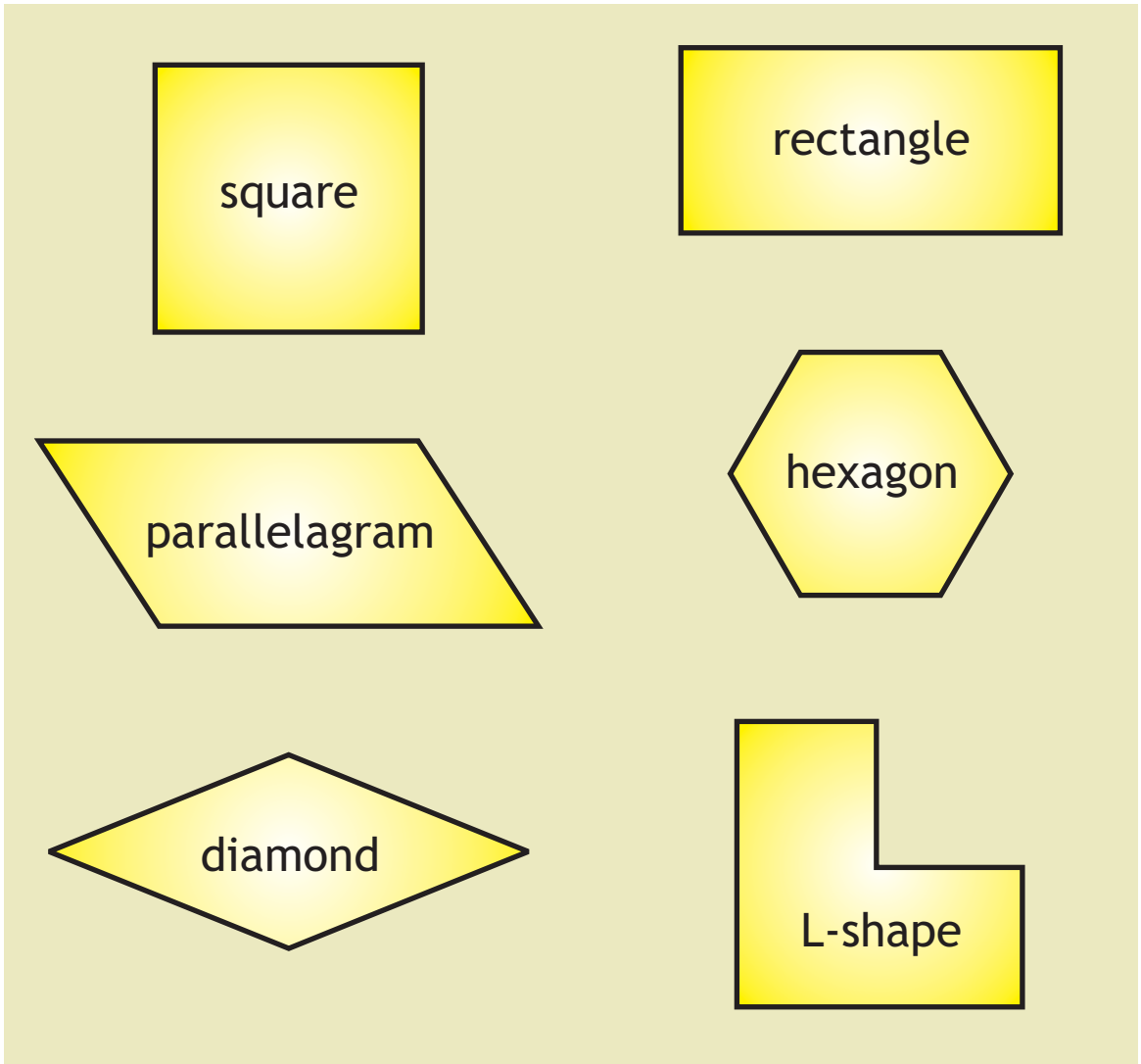
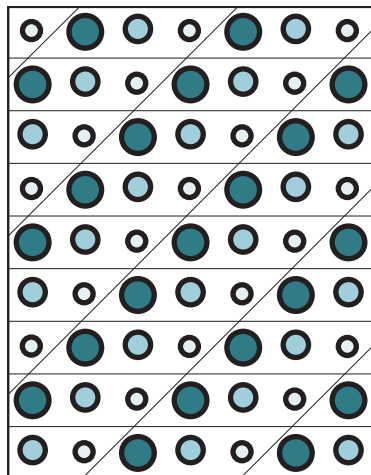
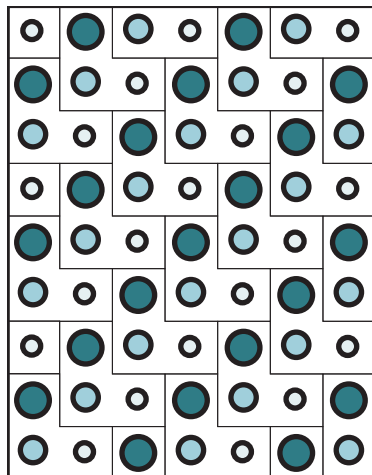


Possible shapes to fill 2-dimensional space



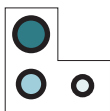
... and many other possibilities
(but almost all are redundant)!

No need to consider other shapes

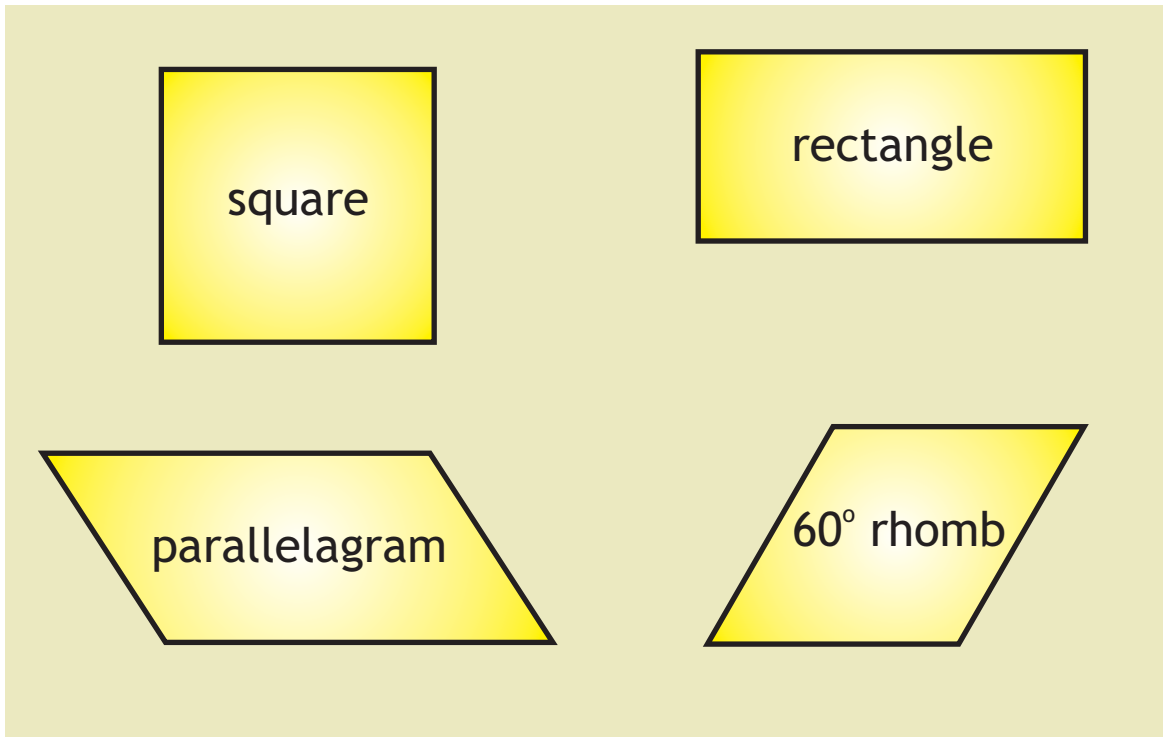


Can make the same pattern with a parallelogram

=> No need to consider the L-shape

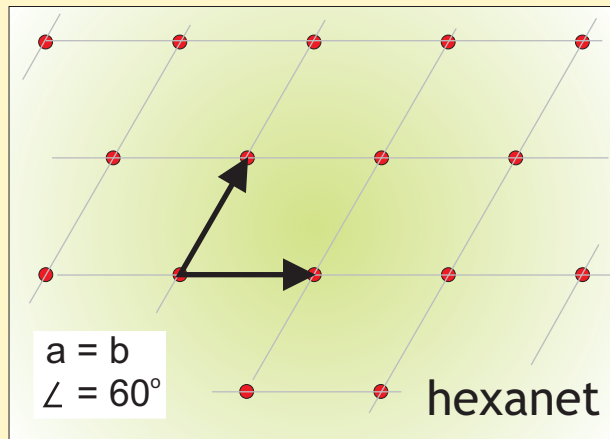
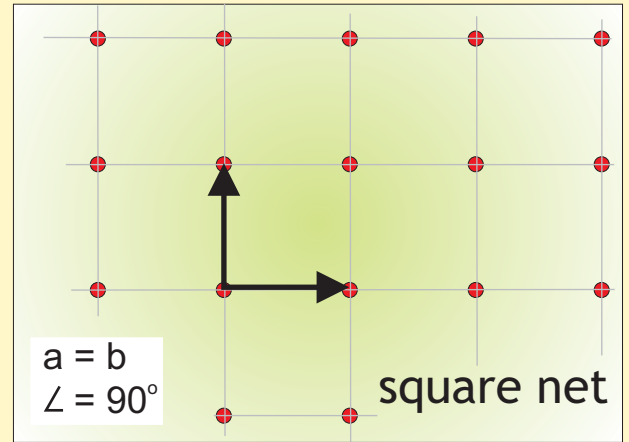
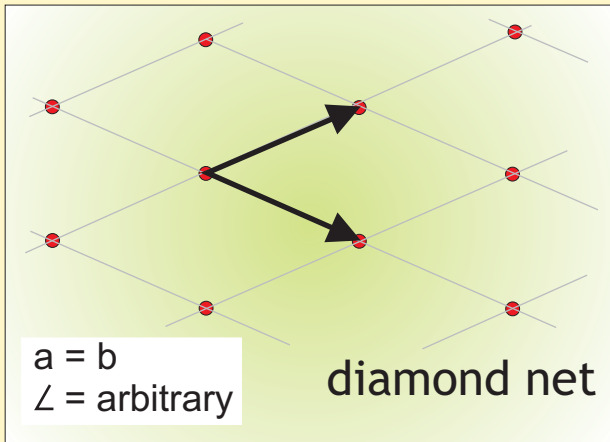
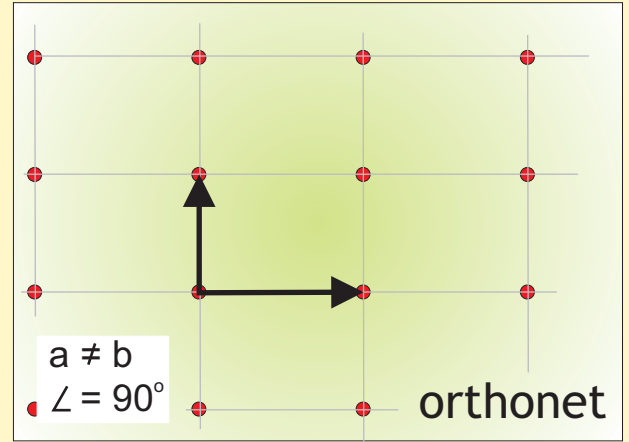
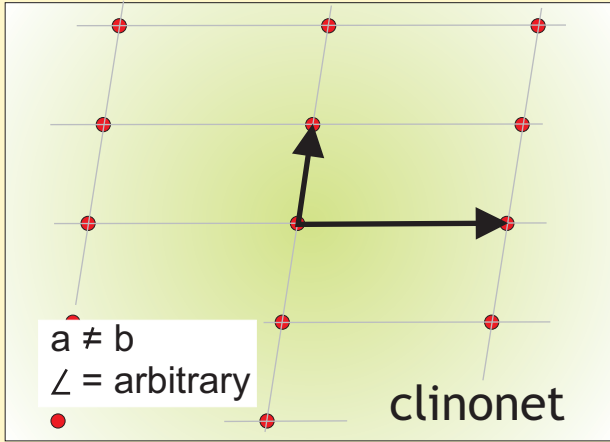


Standard 2-D unit cells used by mineralogists



. . . no others are needed.

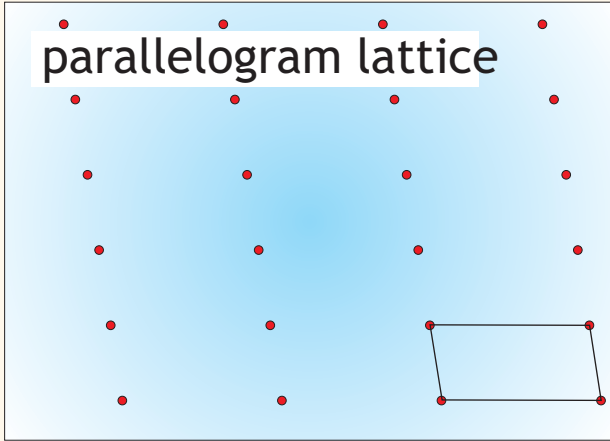
Plane Lattices and Lattice Points



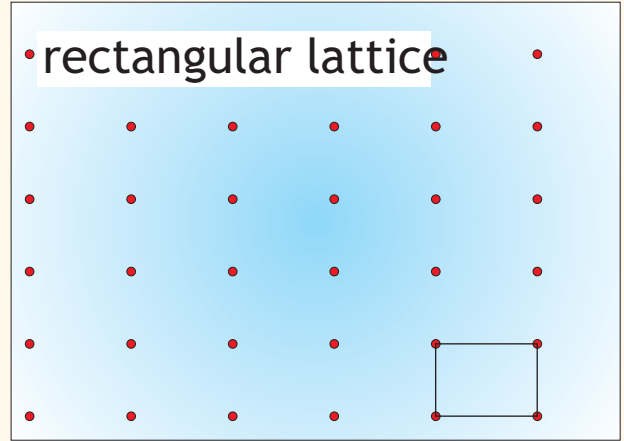
*Orthonet and diamond net
are redundant*

Plane Lattices and Lattice Points

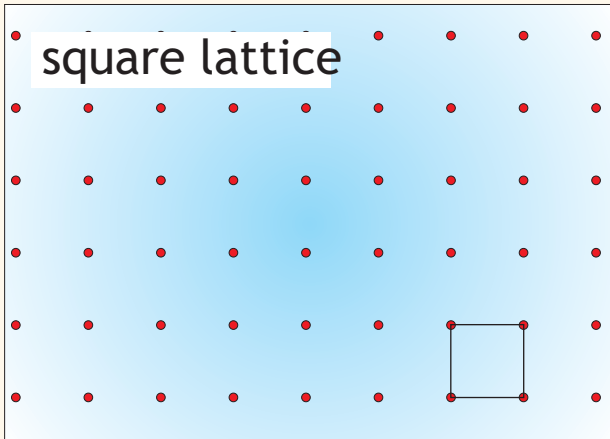
parallelogram lattice



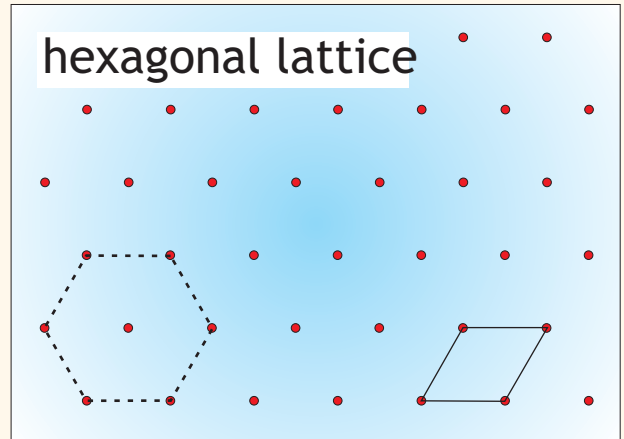
rectangular lattice



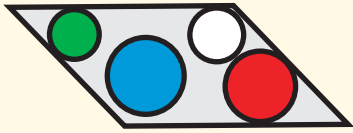
square lattice



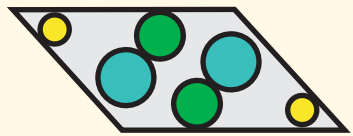
hexagonal lattice



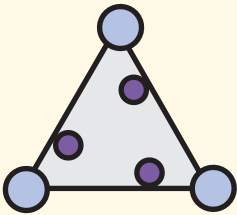
Symmetry Elements



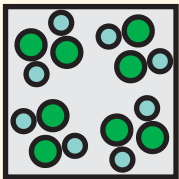
1-fold
symmetry



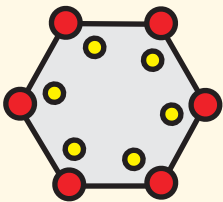
2-fold
symmetry



3-fold
symmetry

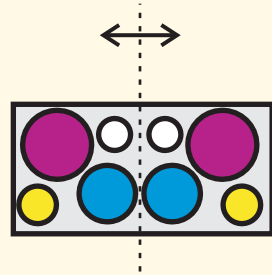


4-fold
symmetry

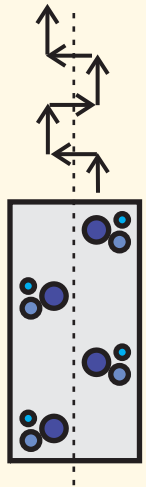


6-fold
symmetry

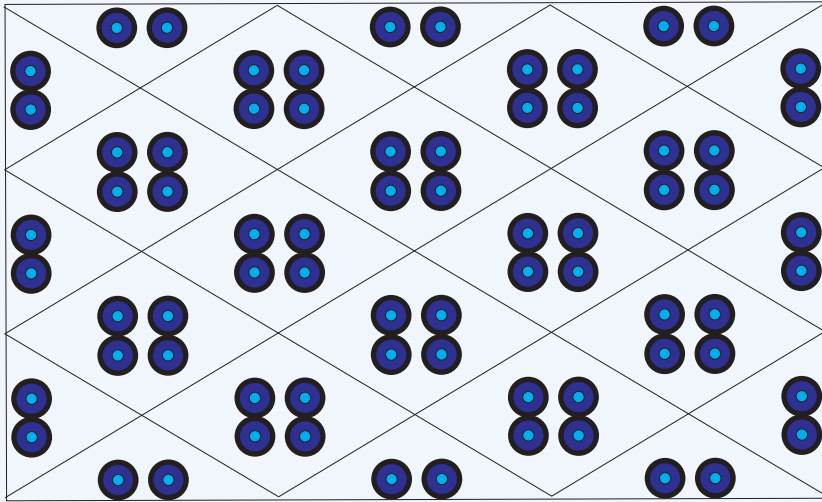
mirror
plane



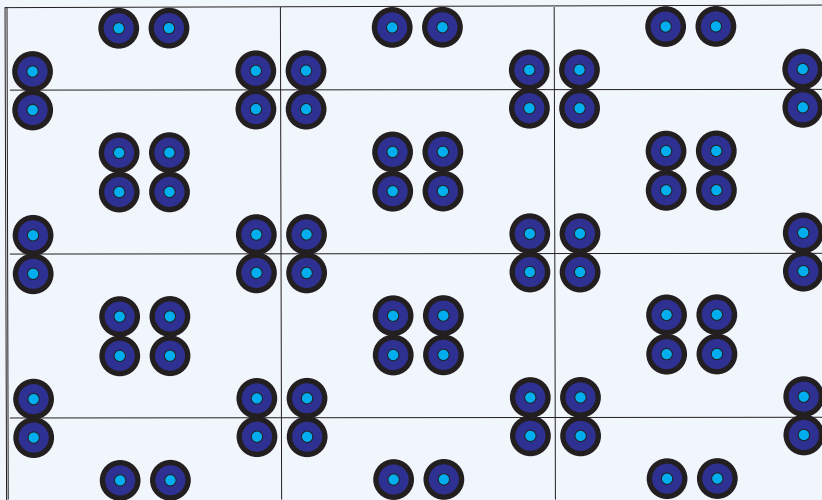
glide
plane



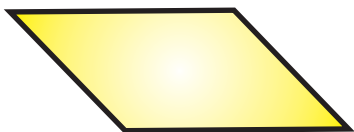
Same pattern . . .
. . . different unit cells



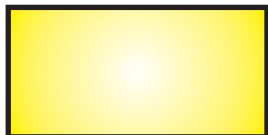
primitive
unit cell



centered
unit cell



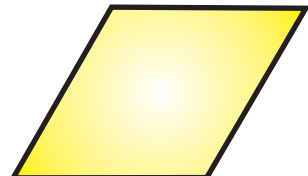
parallelogram



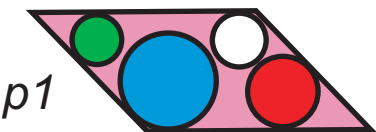
rectangle



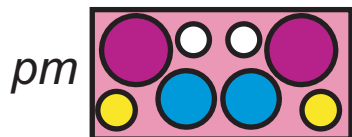
square



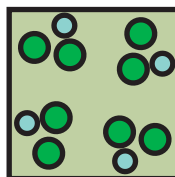
60° rhomb



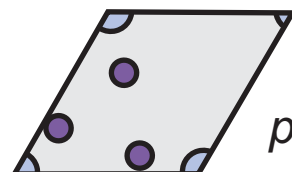
$p1$



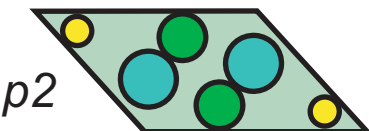
pm



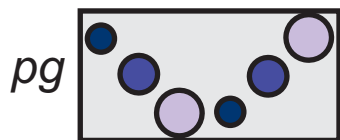
$p4$



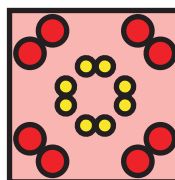
$p3$



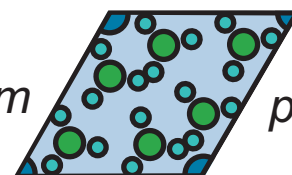
$p2$



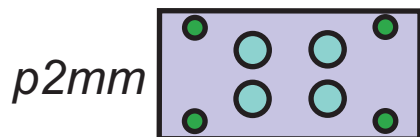
pg



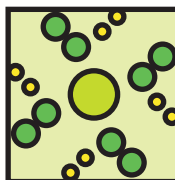
$p4mm$



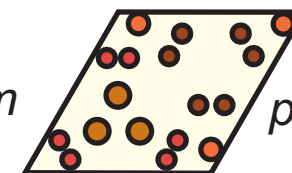
$p31m$



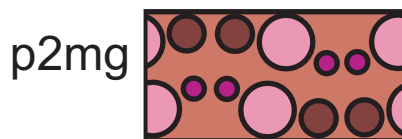
$p2mm$



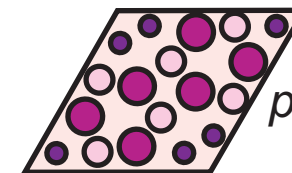
$p4gm$



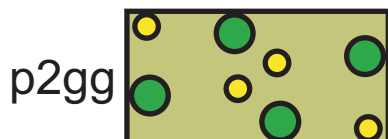
$p3m1$



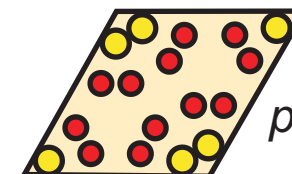
$p2mg$



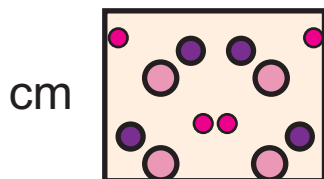
$p6$



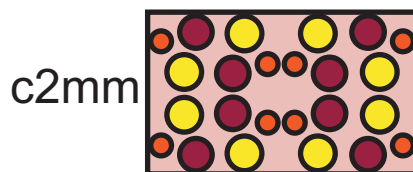
$p2gg$



$p6mm$

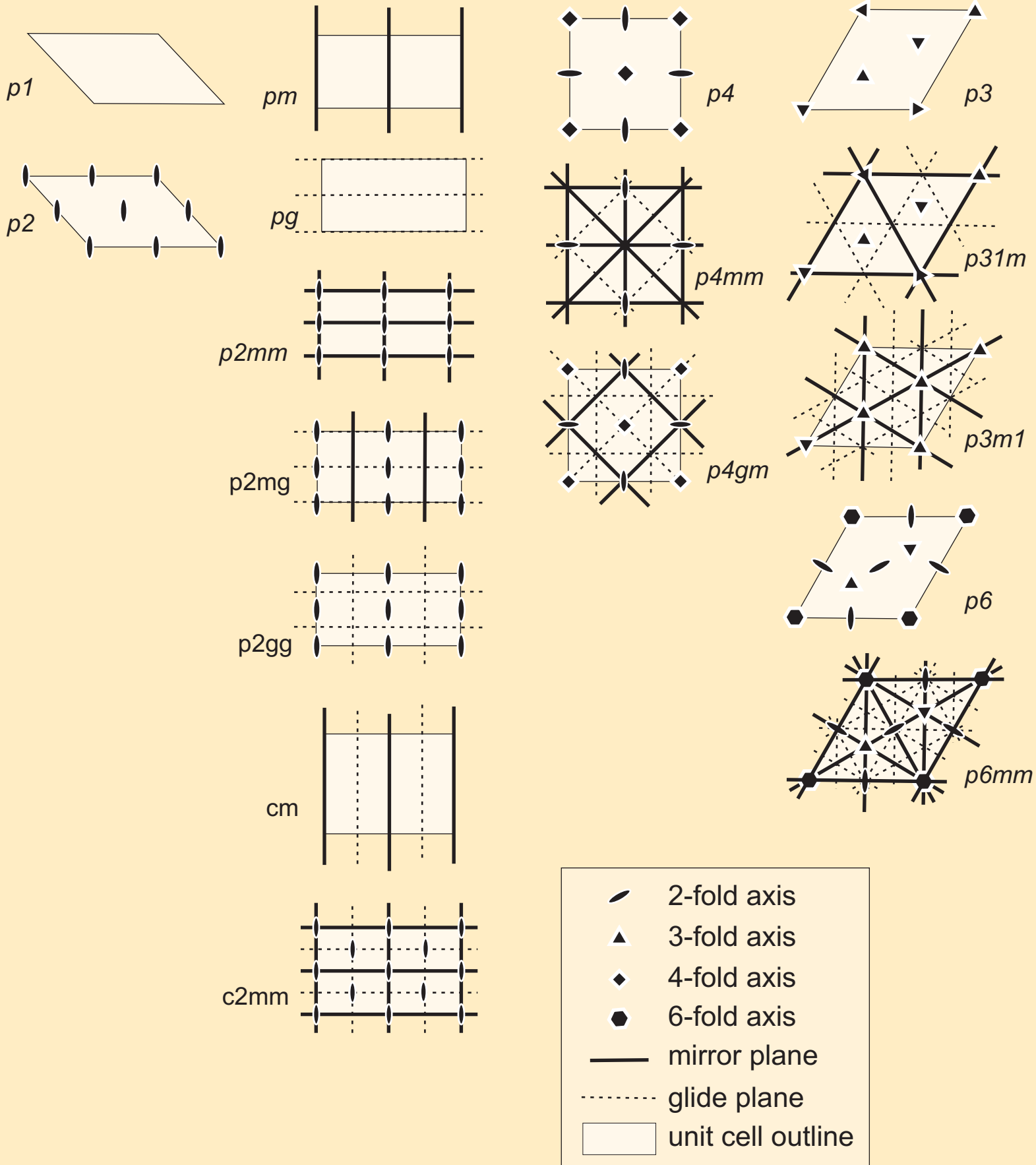


cm



$c2mm$

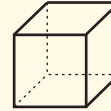
The 17 Plane Group Symmetries



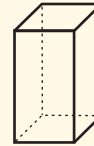
In 3 dimensions

- 6 *systems*
(unit cell shapes)
- 14 lattice
(*Bravais Lattices*)
- 230 *space groups*
- additional kinds of symmetry
glide planes
screw axes

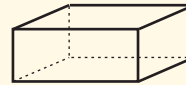
systems



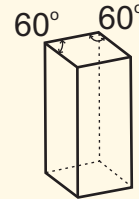
cubic



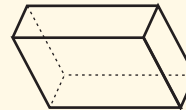
tetragonal



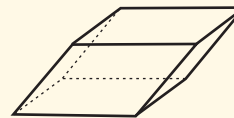
orthorhombic



hexagonal



monoclinic
(2 faces rectangles)



triclinic
(no faces rectangles)

