



# Hexagonal closed packed structure

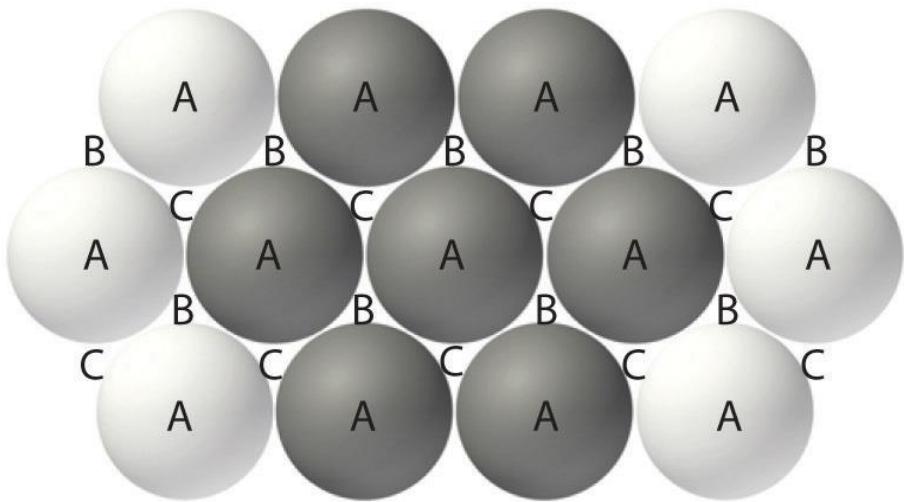
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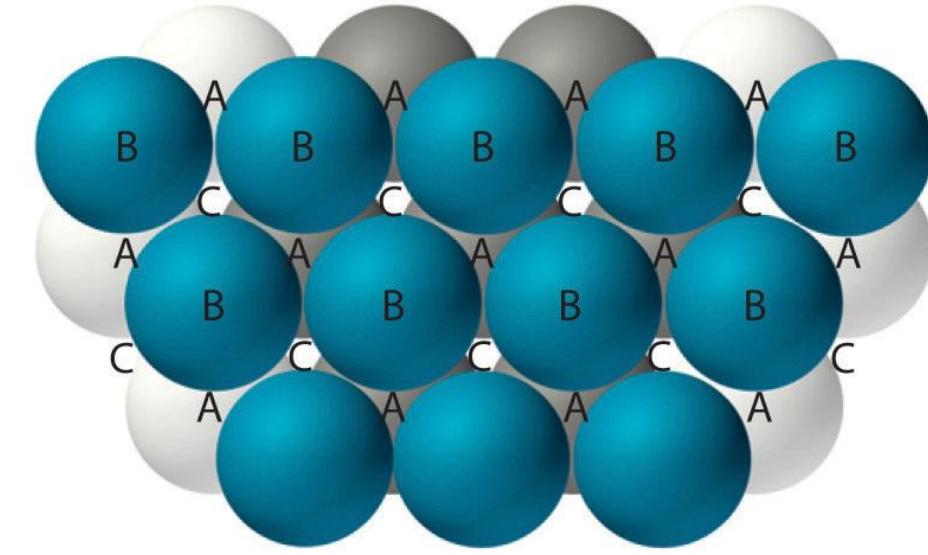
**THAPAR INSTITUTE**  
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(Deemed to be University)

# Closed packed structures

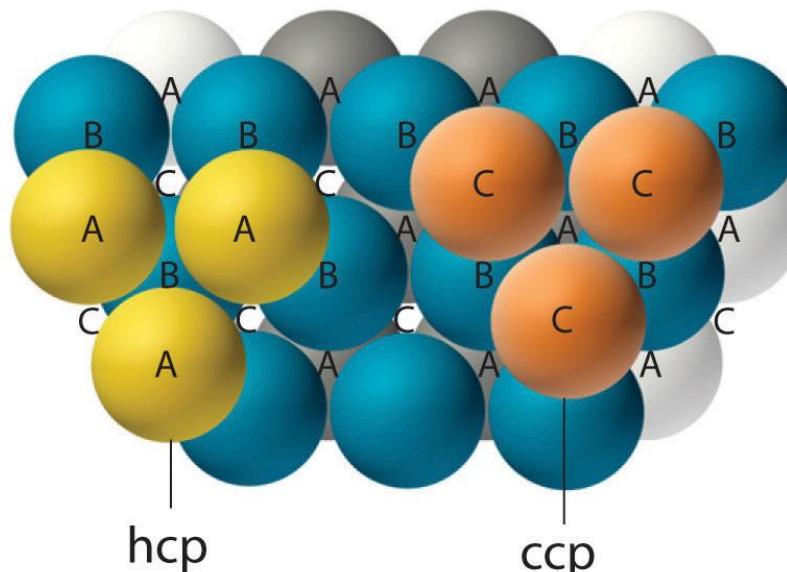
Closed packed structures have highest density in a unit cell



(a) Single layer



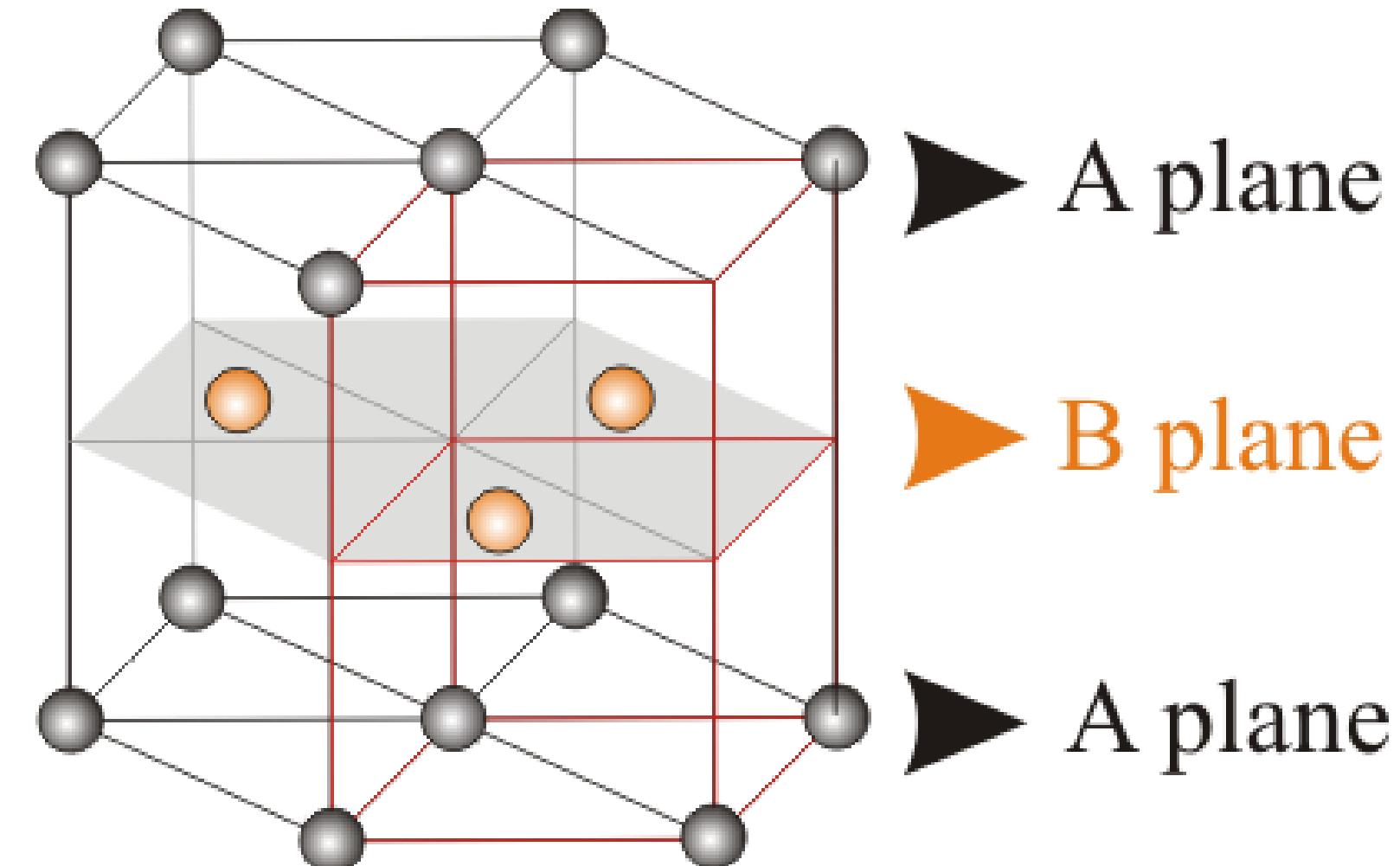
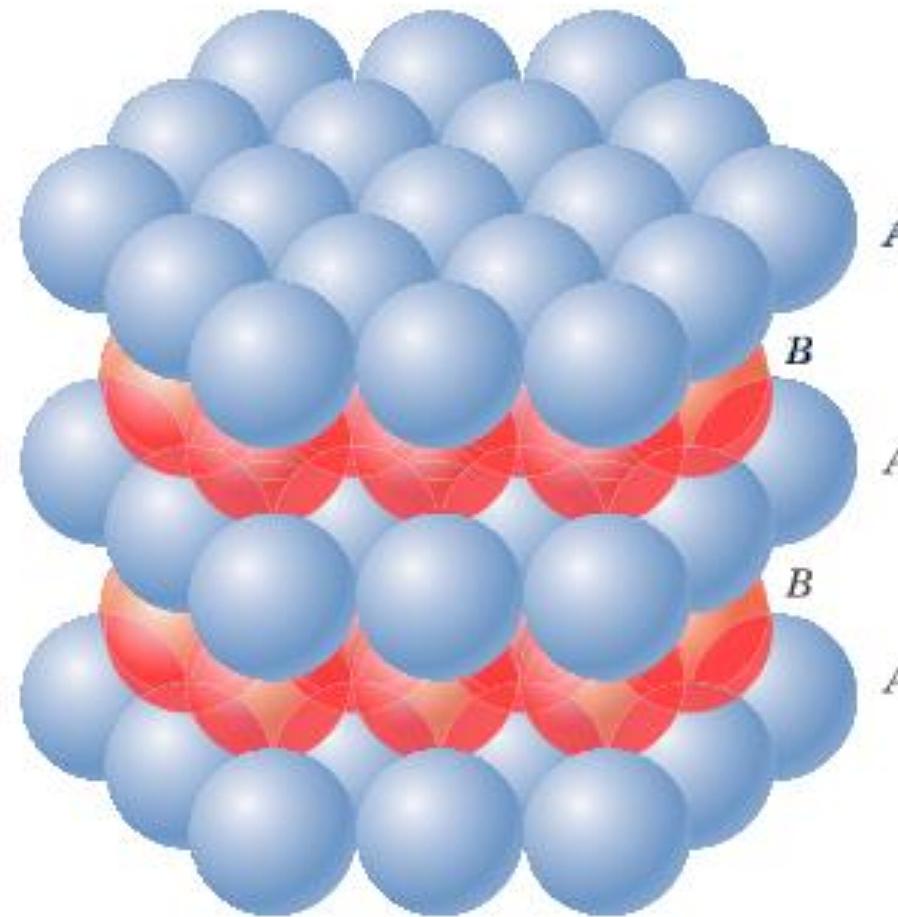
(b) Two layers



(c) Three layers

# Hexagonal closed packed cubic (HCP)

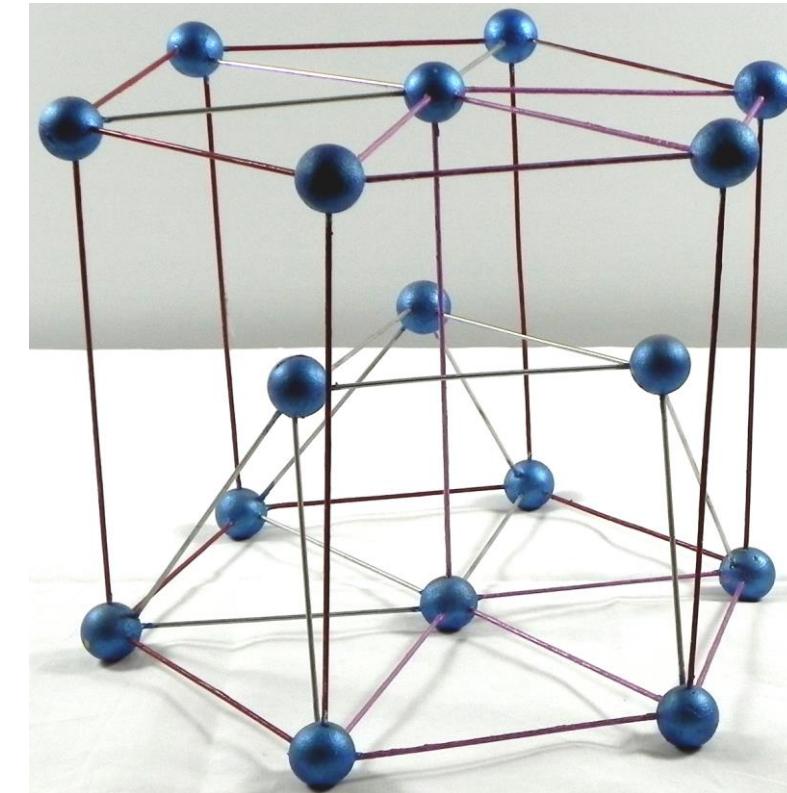
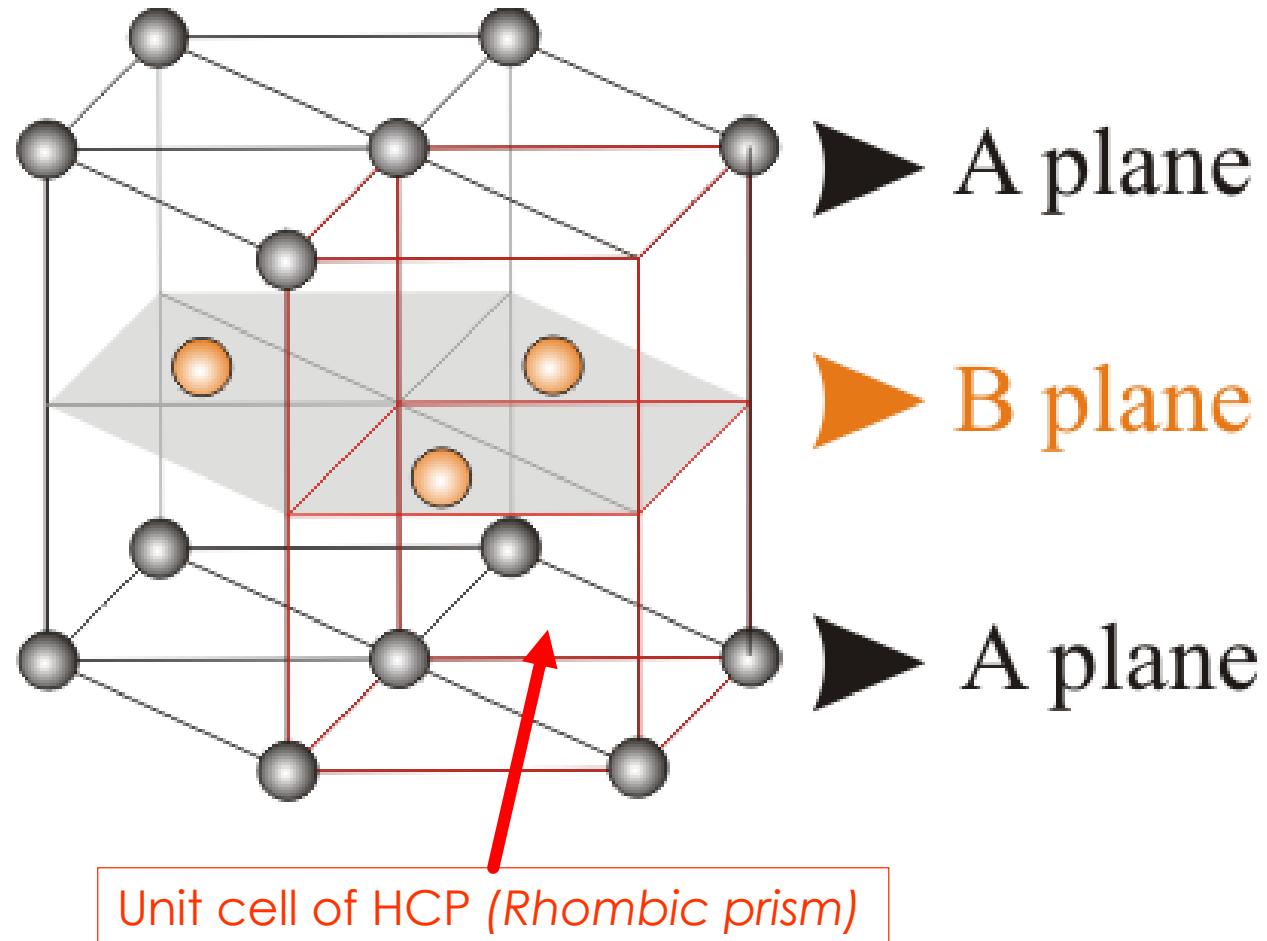
HCP is a closed packed structures



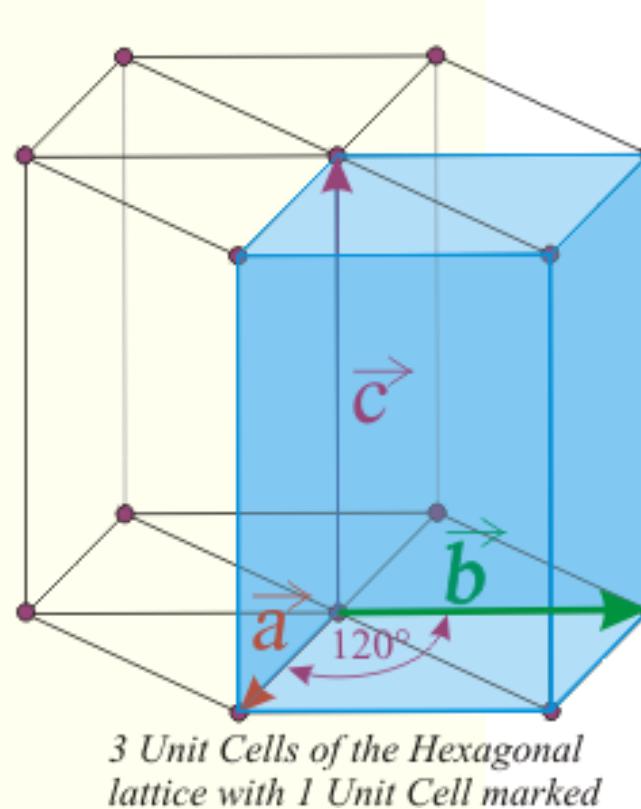
Showing 3 unit cells and  
the rhombic prism UC

# Hexagonal closed packed structure

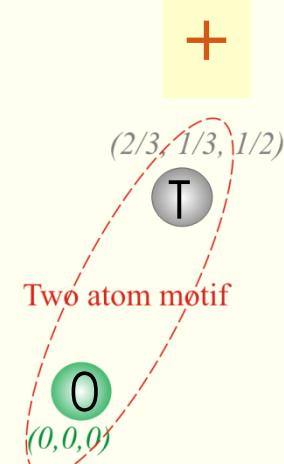
Conventional unit cell Showing 3 unit cells and the rhombic prism UC



## Hexagonal Lattice



3 Unit Cells of the Hexagonal lattice with 1 Unit Cell marked

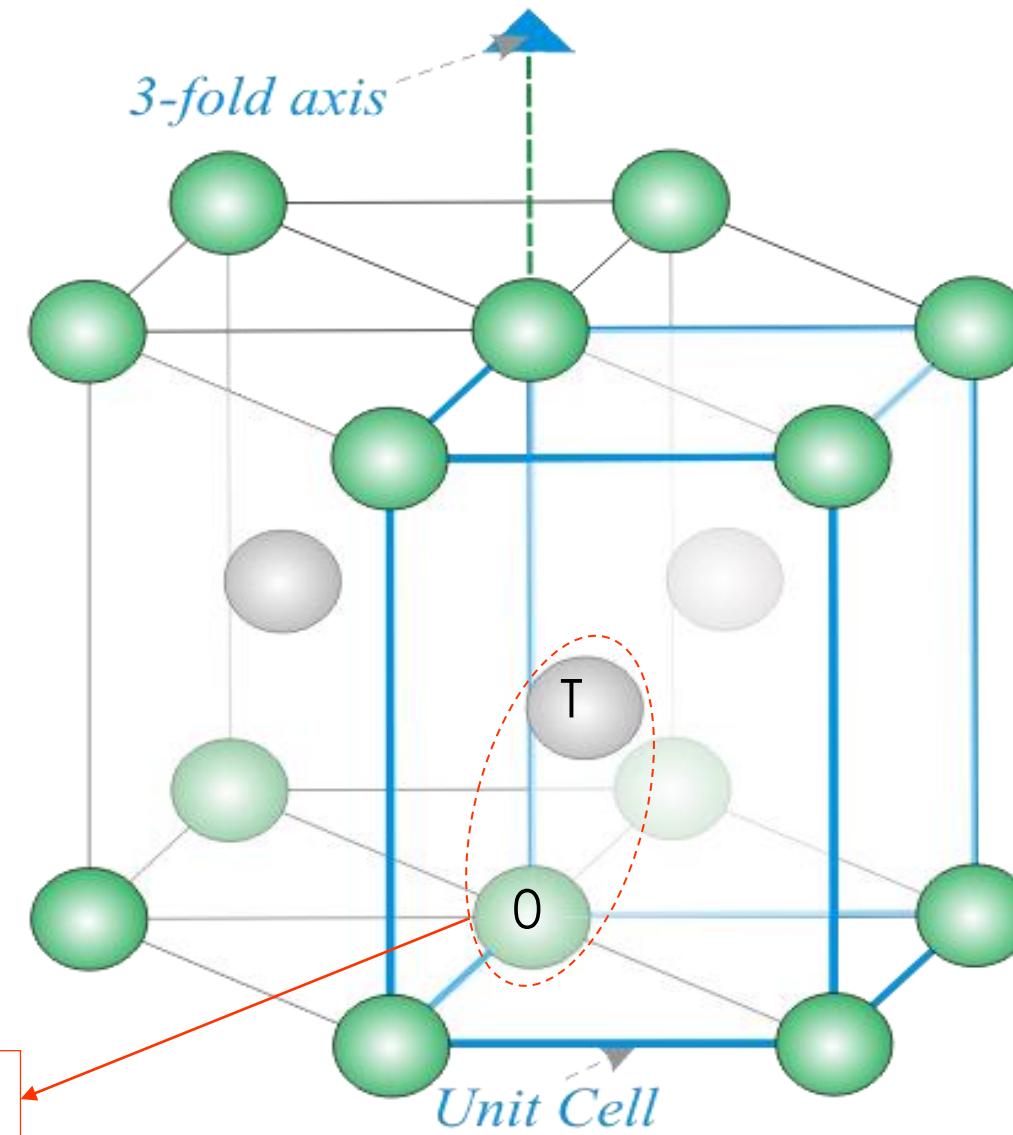


Two atom Motif

- LATTICE → Hexagonal
- MOTIF → Atoms at: O( $0,0,0$ ) & T( $\frac{2}{3}, \frac{1}{3}, \frac{1}{2}$ )

HCP

HCP crystal



Motif

Unit Cell

# Miller-Bravais index notations in HCP

- Directions and planes in hexagonal lattices and crystals are designated by the **4-index** Miller-Bravais notation.
- In the four index notation:
  - the first three indices are a symmetrically related set on the basal plane
  - the third index is a **redundant one** and is introduced to make sure that members of a family of directions or planes have a set of numbers which are identical
  - the fourth index represents the ‘c’ axis ( $\perp$  to the basal plane).

# Miller-Bravais index notations in HCP

- The redundant index can be obtained from other two.
- This is called as symmetry condition. If this condition gets satisfied then and only then the plane exists.

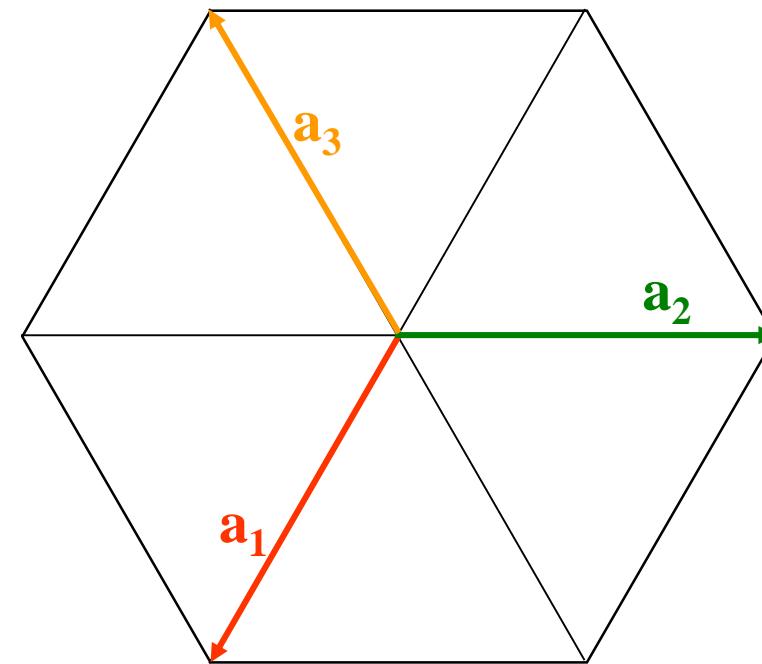
$$(h \ k \ i \ l)$$

$$i = -(h + k)$$

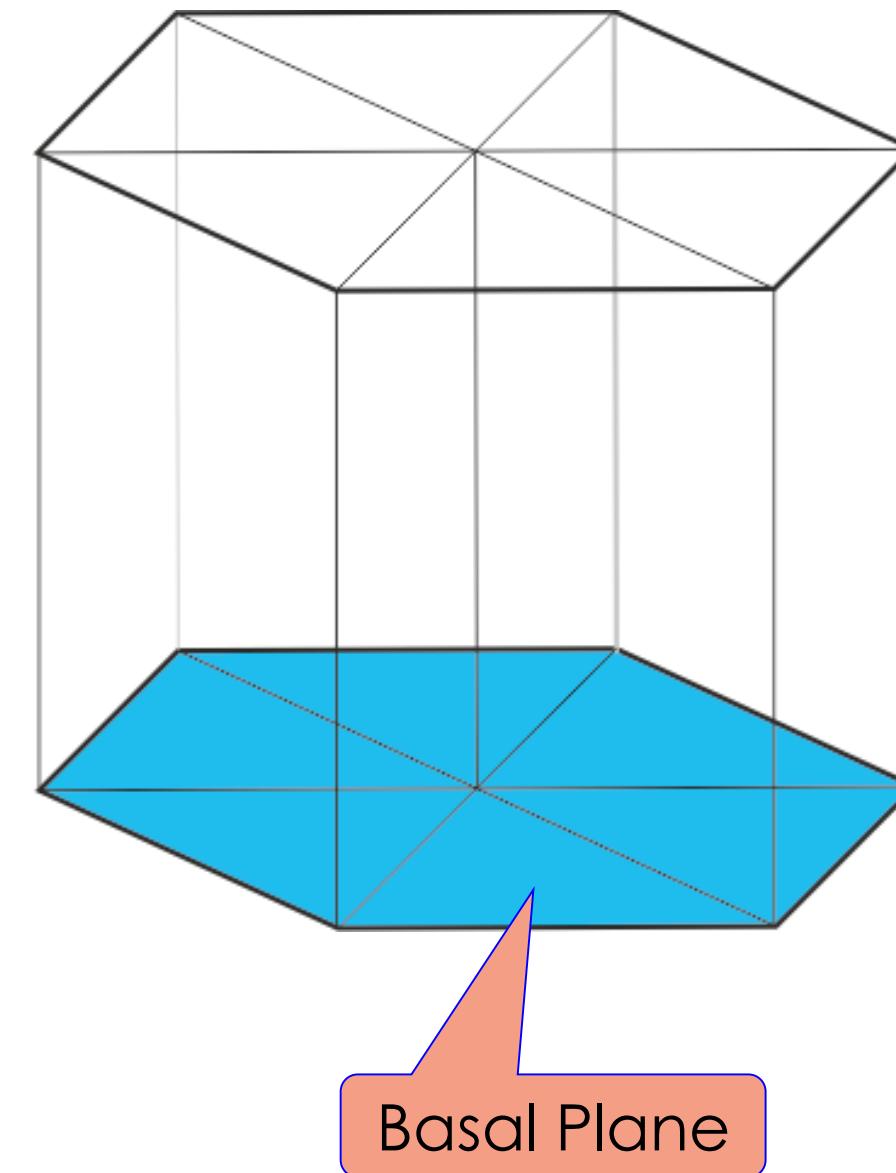
$$(hkl) \rightarrow (hkil)$$

$$(110) \rightarrow (11\bar{2}0)$$

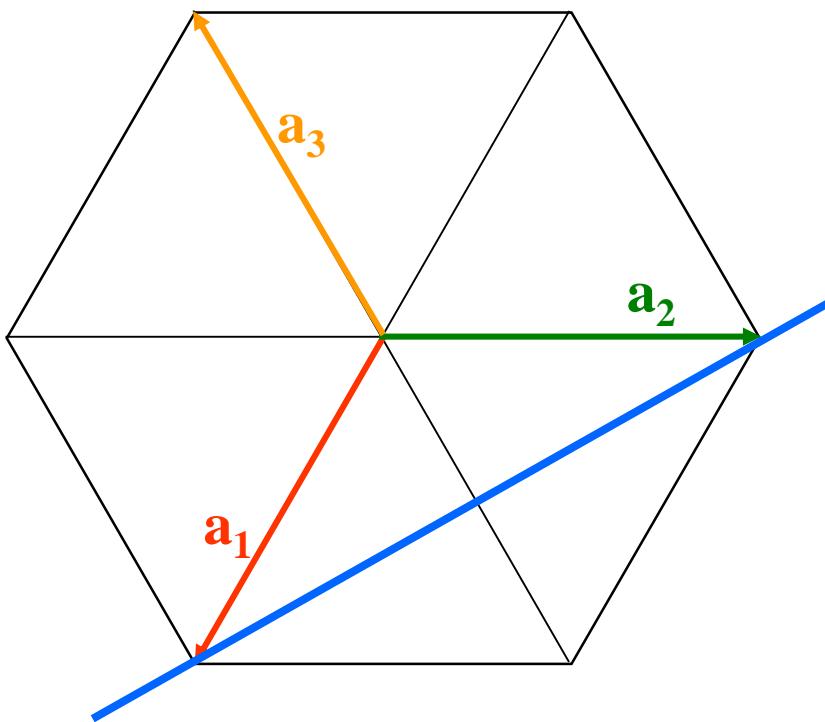
## Basal Plane



Intercepts  $\rightarrow \infty \infty \infty 1$   
Plane  $\rightarrow (0 0 0 1)$



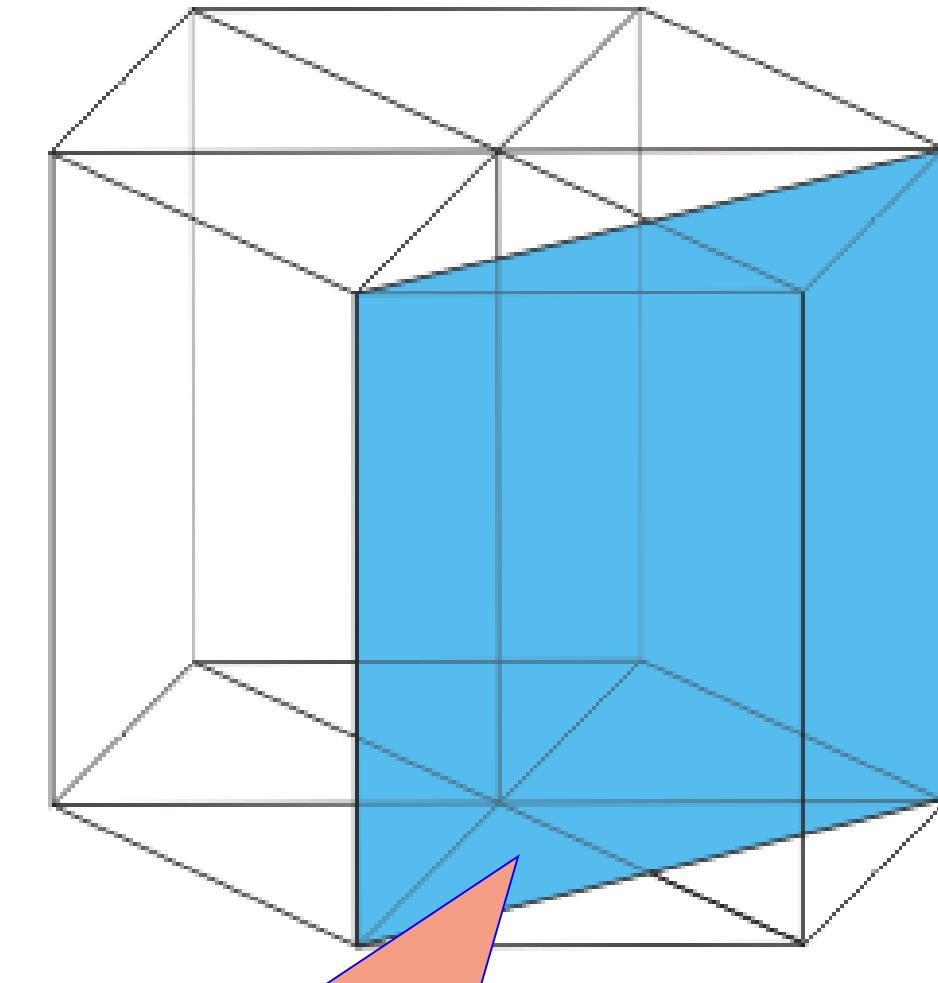
## Prism planes



$$(h \ k \ i \ l)$$

$$i = -(h + k)$$

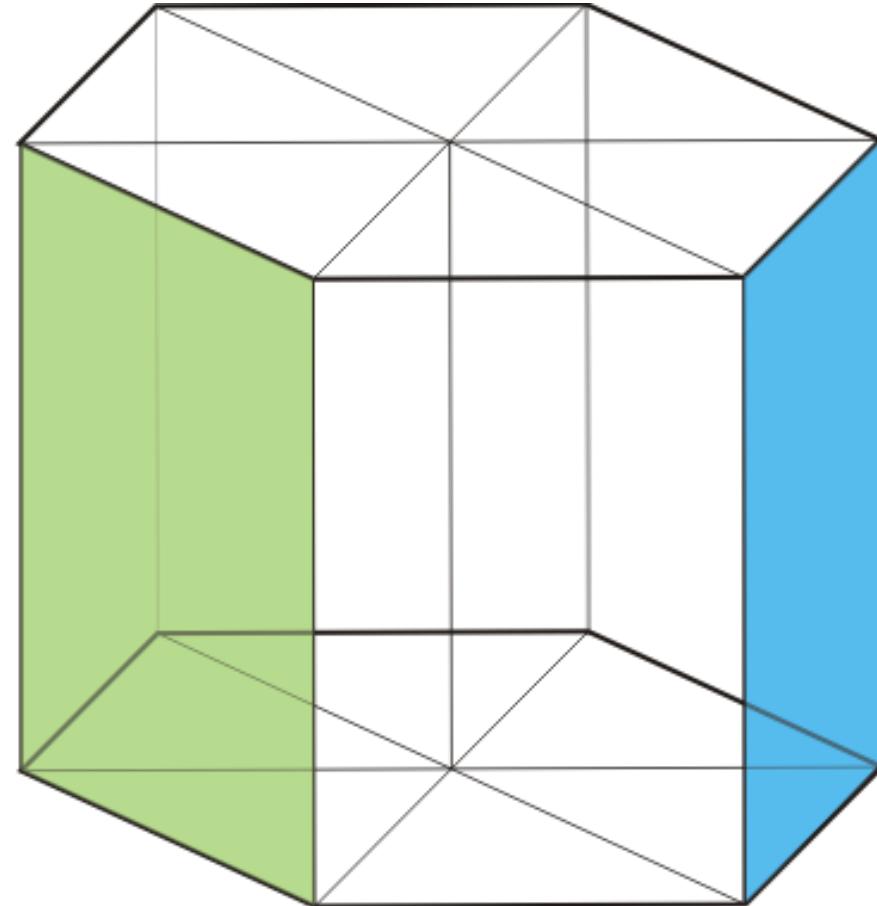
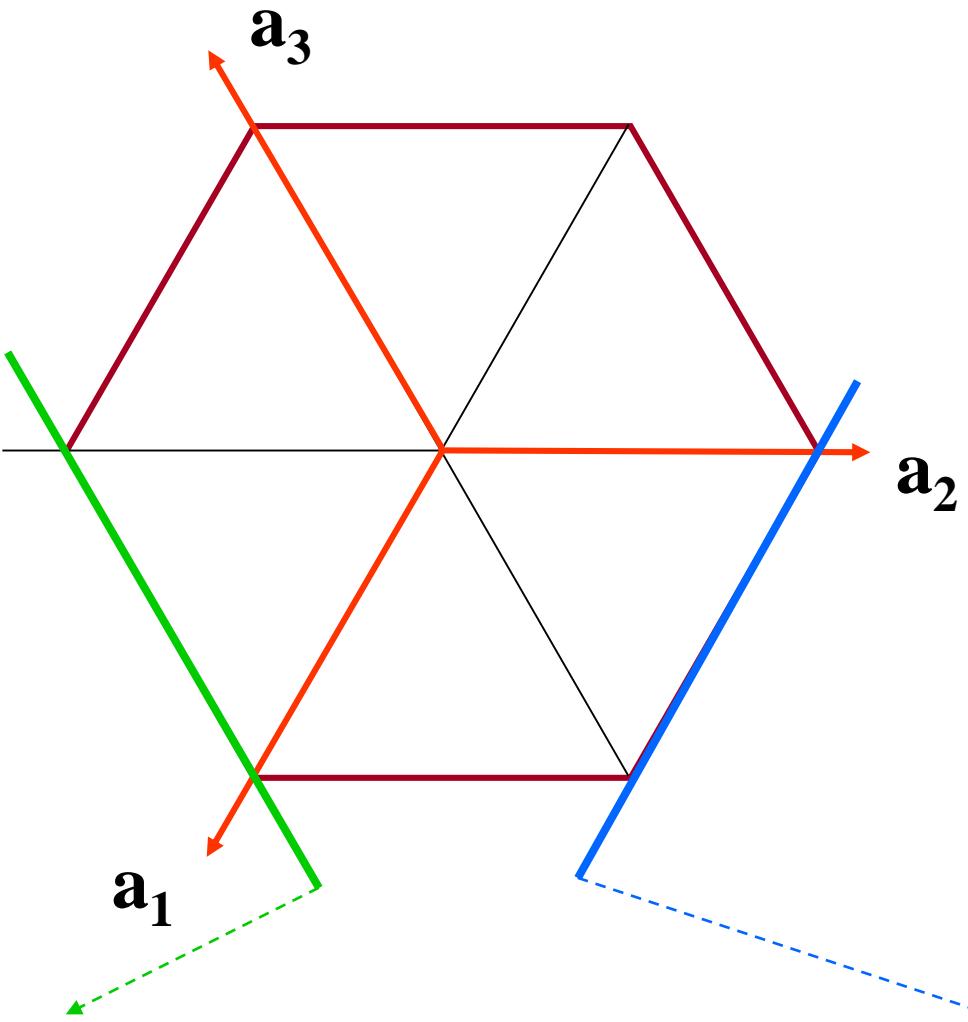
Intercepts  $\rightarrow 1 \ 1 - \frac{1}{2} \ \infty$   
 Plane  $\rightarrow (1 \ 1 \ \bar{2} \ 0)$



Planes which have  $\infty$  intercept along c-axis (i.e. vertical planes) are called Prism planes

# MI for planes in HCP

'Green' and 'blue' planes belong to the same family



Intercepts  $\rightarrow 1 -1 \infty \infty$

Miller  $\rightarrow (1 \bar{1} 0)$

Miller-Bravais  $\rightarrow (1 \bar{1} 00)$

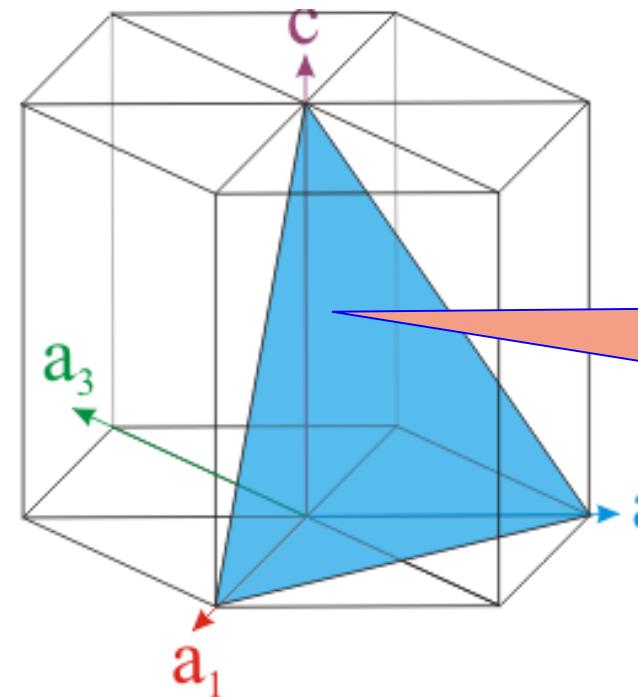
Intercepts  $\rightarrow \infty 1 -1 \infty$

Miller  $\rightarrow (0 1 0)$

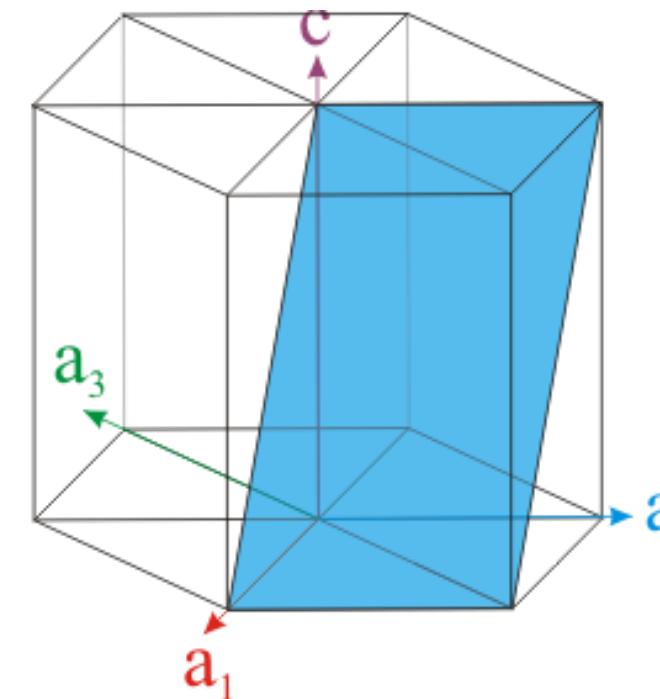
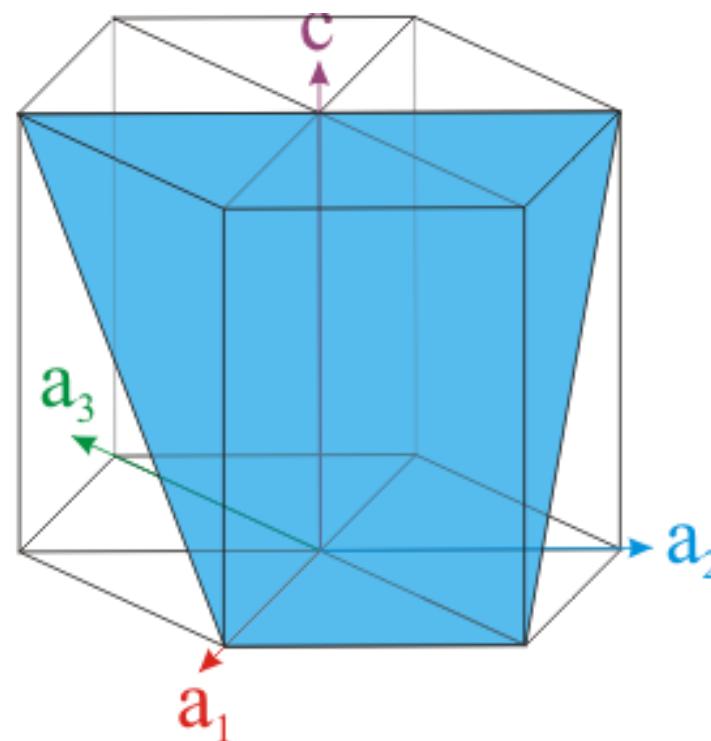
Miller-Bravais  $\rightarrow (0 1 \bar{1} 0)$

# MI for planes in HCP

## Pyramidal planes

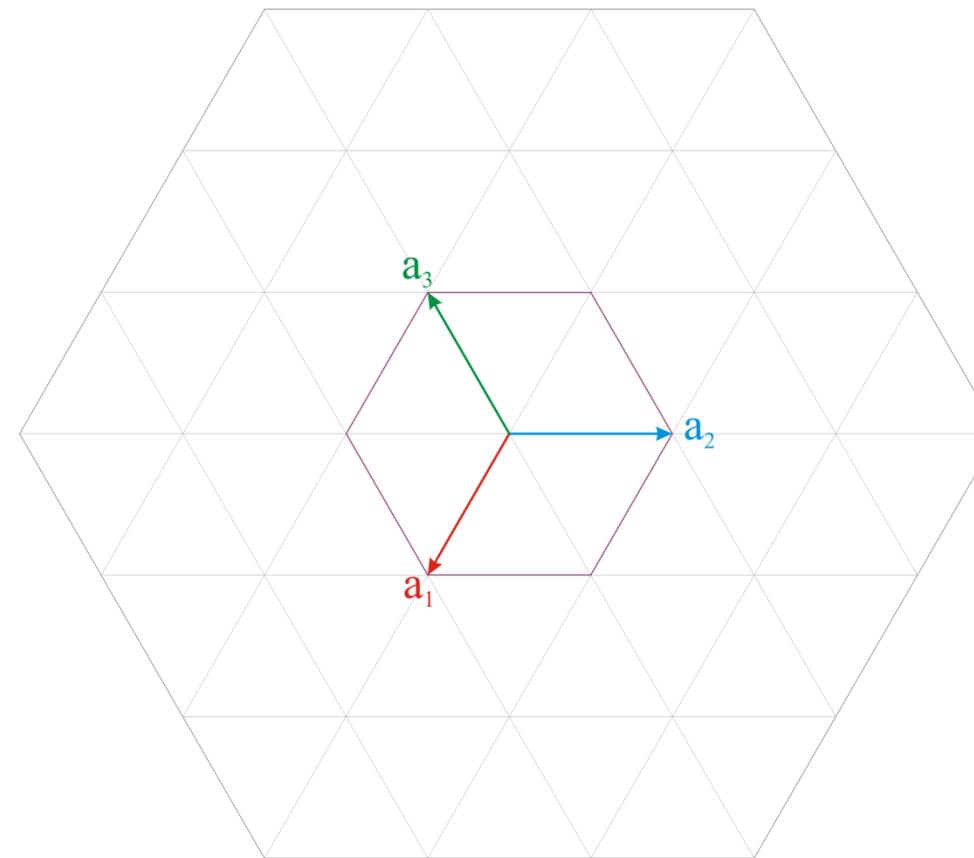


Inclined planes which have finite intercept along c-axis are called Pyramidal planes



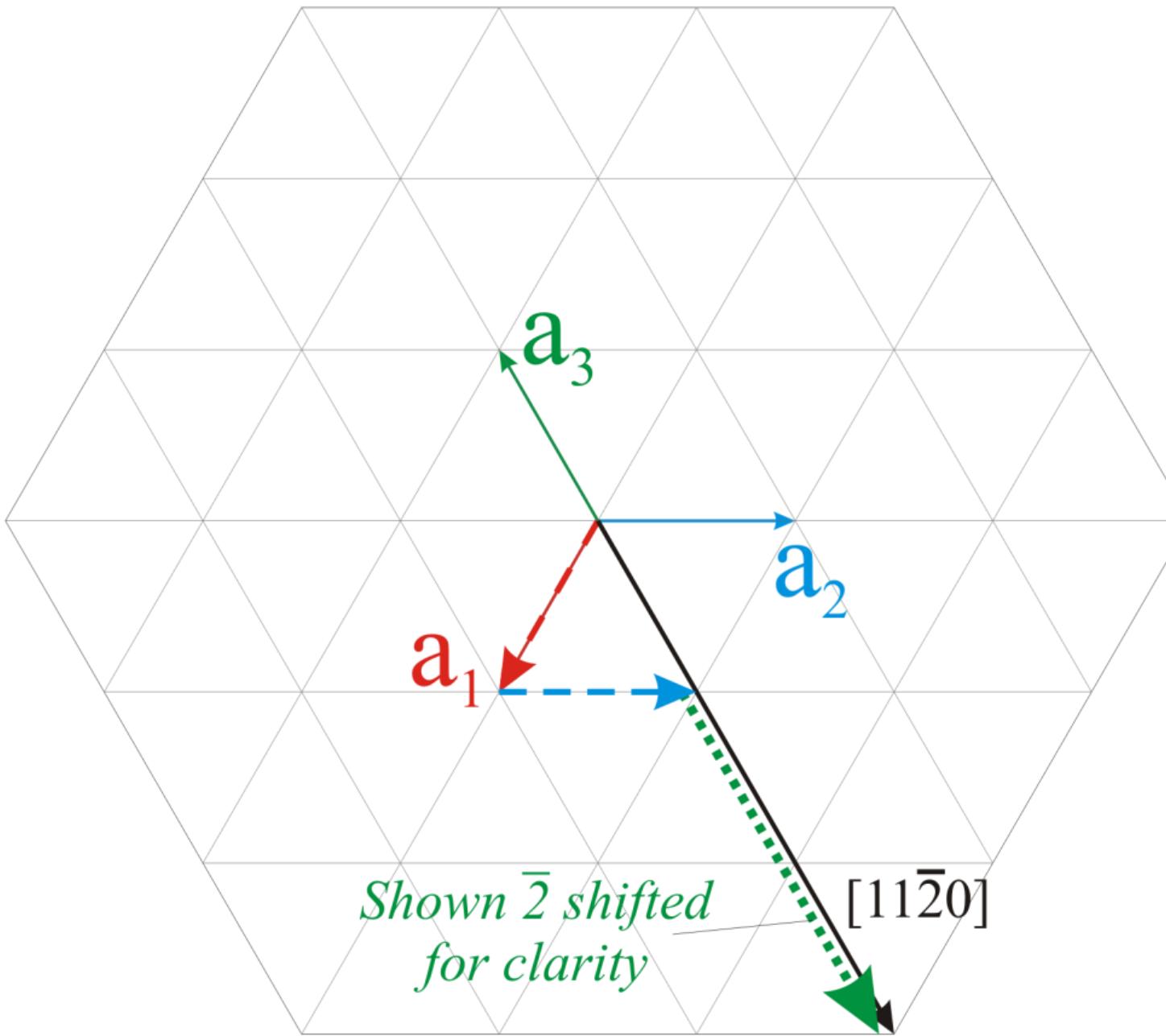
# MI for direction in HCP

1. Basis vectors  $\mathbf{a}_1$ ,  $\mathbf{a}_2$  &  $\mathbf{a}_3$  are symmetrically related by a six fold axis.
2. The 3<sup>rd</sup> index is redundant and is included to bring out the equality between equivalent directions.
3. In the drawing of the directions we use an additional guide hexagon 3 times the unit basis vectors ( $\mathbf{a}_i$ ).

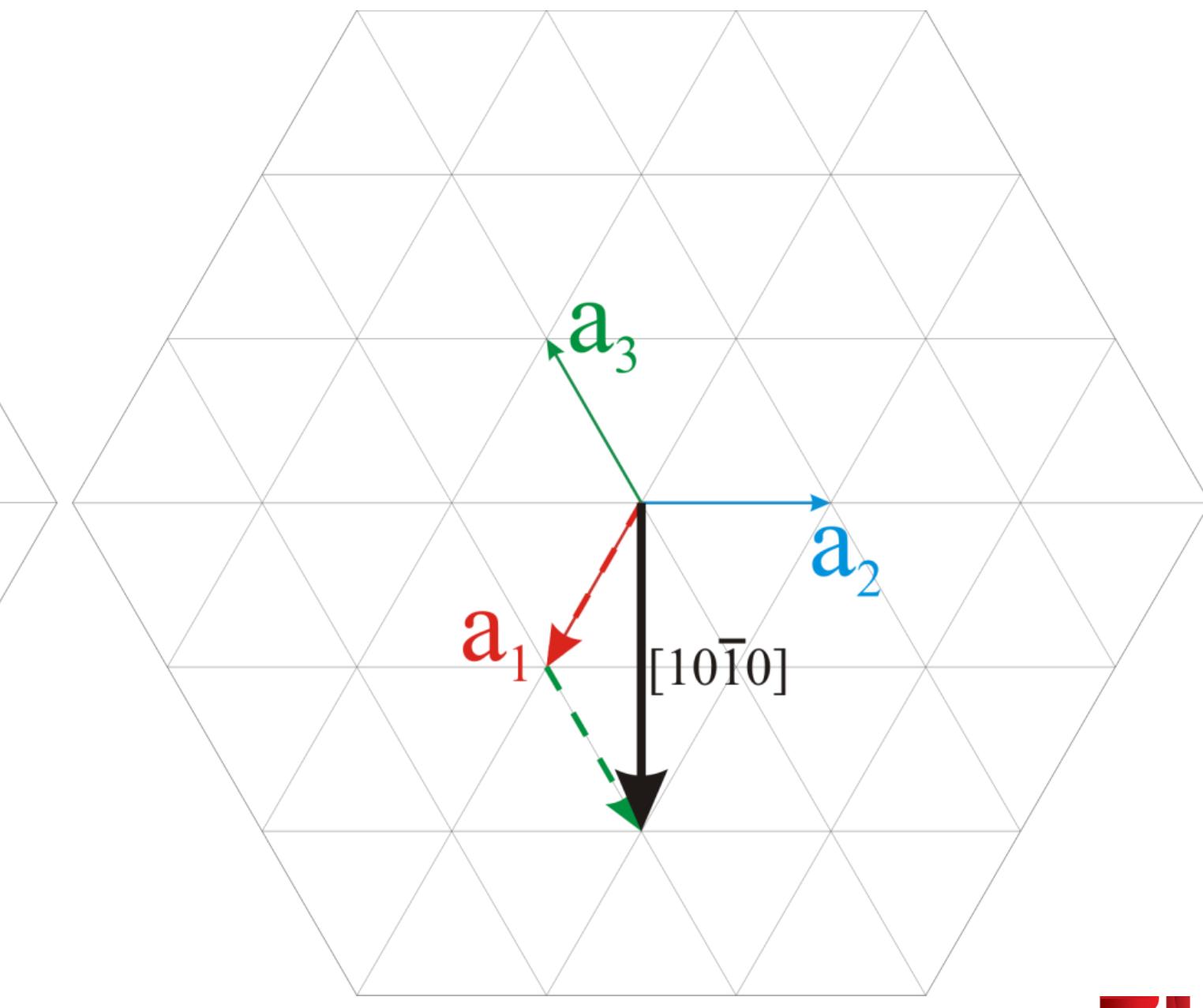


Guide Hexagon

Draw the  $[11\bar{2}0]$  direction



Draw the  $[10\bar{1}0]$  direction



## Remember

- Only atoms whose center of mass lies on the plane has to be count.
- In the BCC crystal, the (111) plane partially intersects the atom at the body center  $(\frac{1}{2}, \frac{1}{2}, \frac{1}{2})$ . This atom has to be excluded from the calculation.

# Summary

1. The HCP system have 4 index system to denote planes called as Miller-Bravais system.
2. The planes in HCP can be drawn by three Miller indices only. The third Miller indices is redundant in nature. It is used for symmetry.
3. The planes on the top and bottom are called as basal planes.
4. The planes parallel to c axis are called as prism planes.
5. The planes which have intercept on the c axis are called as pyramidal planes.
6. HCP has highest packing density  $\sim 74\%$
7. Ideal  $c/a$  ratio for HCP is 1.63