Glide Systems and Ease of Deformation

Note: this module is pretty much self-contained and understandable in the context of what is explained in the backbone. Nevertheless, it is advantageous to give the two science modules listed a quick look, too.

Illustration

If one dislocation moves through a crystal, it shears one part with the respect to the other part a tiny little bit. Many dislocations of the same type moving the same way just make the shear larger. This is shown on the left-hand side of the figure below.
You can only produce very specific *deformations* this way.

- No, you can't just have your dislocations move some other way. In real crystals there is a limited number of planes on which dislocations can move, *and* a limited number of shear directions (called "Burgers vector" for reason that need not concern us here) they can produce. The two limits come straight from the fact that Burgers vectors must be the shortest possible translation vectors of the lattice, and that glide planes should be the ones with the highest packing density of atoms.
  So let's pick a second set of an allowed plane (called "glide plane") and move a dislocation there in an allowed shear direction. This is shown on the right-hand side of the figure below.

Science link

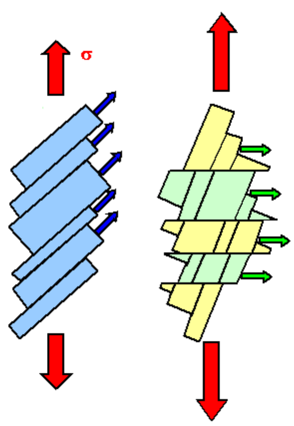
Defor-mations

- Considering that the steps produced by moving a dislocation are very small, what kinds of shapes can we make this way? This is not an easy question. The really tough question, however, is:
  How many independent combinations of glide planes / Burgers vector or, as we going to call that "**glide systems**", do you need to be able to produce *any* shape?
  If you know and enjoyed "The Hitchhiker's Guide to the Galaxy" from **Douglas Adams** , your guess probably would be "42". Well, you are wrong. The proper answer is "5". Sorry about that but *the question* to the answer "42" is still not known.
  All material scientists know that the proper number is 5 but very few know how it is derived. It is a bit like the 14 Bravais lattices.

Science link

Dislo-cations

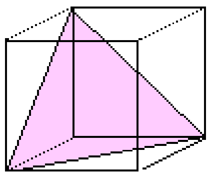
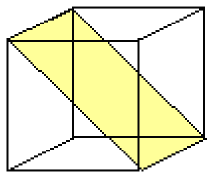
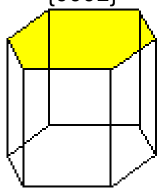
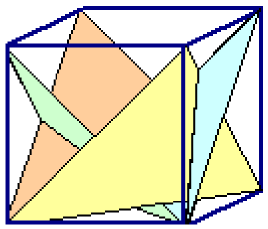
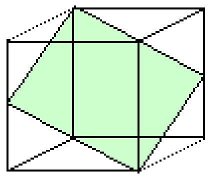
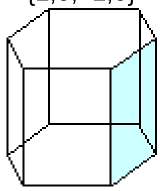
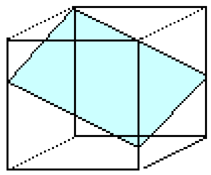
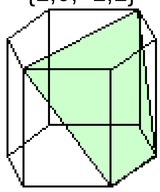
- Just *five* glide systems are enough to produce *any* kind of shape from your original body by running a sufficient number of dislocations through it.



Deformations by dislocation movement on one or two glide systems.

- You can change the original rod into many shapes by operating one or two glides systems - but not into *all* possible shapes. For that you need five glide systems

So how many glide system do we have in the more important Bravais lattices / crystals? My students always find this a very hard exercise to do, even so it only contains "elementary" geometry. Anyway, here is the answer.
(Ignore the Miller indices given for the lattice planes if you are not acquainted with them and even if you are, don't worry about the 4-indices system for the hexagonal crystal).

Densely packed planes in fcc, bcc and hex lattices or the major glide planes for dislocations in those crystals. Some prominent crystals using specific glide planes are indicated.		
fcc	bcc	hcp
{111}  Al, Ag, Cu, Ni, γ- **Fe**, ..	{110}  α- **Fe**, W, Mo, β-brass	{0001}  Cd, Zn, Mg, Be, Al_2O_3
 There are four {111}-type planes	{211}  α- **Fe**, W, Mo, Na	{1,0,–1,0}  Ti, Zr
	{321}  α- **Fe**, K	{1,0,–1,1}  Ti, Mg (rarely)
{111} most dense. No other planes come close	**{110}** most dense but the others are quite similar	**{0001}** most dense but others are close.
All Burgers vectors are **a/2<110>** type.	All Burgers vectors are **a/2<111>** type.	Shortest Burgers vector is **a/ 3<1,1,–2,0>**. Others are possible.
Number of crystallographically identical planes:		
{111}: **4** (111), (-111), (1-11), (-1-11)	{110}: **6** {211}: **12** {321}: **24**	{0001}: **1** {10–10}: **3** {10–11}: **6**
Number of different Burges vectors scontains in a plane		
{111}: **4** (111), (-111), (1-11), (-1-11)	{110}: **2** {211}: **1** {321}: **1**	{0001}: **3** {10–10}: **1** {10–11}: **1**
Number of glide systems = combinations plane / Burgers vector		
12 (= 3 · 4)	{110}: **12** = 6 · 2 {211}: **12** = 12 · 1 {321}: **24** = 24 · 1	{0001}: **3** = 1 · 3 {1,0,–1,0}: **3** = 3 · 1 {1,0,–1,1}: **6** = 6 · 1

So we have enough glide systems for fcc and bcc crystals. In hexagonal systems things are more complex. The easy basal or {0001} plane supports only 3 shortest Burger vectors. Deforming an hexagonal crystal thus needs to activate one or both of the other glide planes and unfavorable Burgers vectors, which is possible but more difficult. It follows that hexagonal crystals must be less ductile and more brittle then their cousins, which they are, indeed. That is one of the reason why hexagonal magnesium (Mg), a metal offering an extremely good strength-to-weight ratio, is not (yet) used as much as it should be.

- Note that the whole business of glide systems in bcc crystals is more tricky then for fcc crystals. While there are more glides systems, none of them is as easy to operate as the **{111}/<110>** system of the fcc crystals. In comparison to *fcc* crystals, this tends to make *bcc* crystals tougher to deform, somewhat more brittle, and in particular given to "cold shortness", or becoming completely brittle at low temperatures.
  Note too that our beloved iron uses *all* possibilities offered, in contrast to other bcc crystals that have some favorite glide systems. That may help the smith when he bangs it into shape but doesn't make the science of deforming iron much easier.