Welcome back!

As announced in the last unit, we now want to explore translational symmetry more deeply. We want to look what different kinds of symmetry elements exist, which have a translational component. These are, of course, pure translations, but also glide planes and screw axes!

For a start, we will stick to the 2D plane, before we will explore translational symmetry elements in 3D space in the next chapter... and in this unit we will explore glide planes.

Look at these symmetrical 2D patterns: all these patterns can be described by one of only 17 of the so-called Wallpaper groups or plane groups. This means, concerning their symmetry properties, there are only 17 principally different repeating patterns in the plane.

Of course, there are more possibilities to design different cloths, textiles, wallpaper or the like, because the motif can be different, it can have shapes whatsoever, but concerning their periodic arrangement, this is restricted to only 17 possibilities.

Once more, remember, the reason for this is based on the fact, that the different kinds of symmetry elements cannot be combined arbitrarily, because some are not compatible with a repeating lattice!

Let’s look at some of these patterns more closely, for instance this one here - obviously this 5-fold rotational star is repeated in a simple, primitive manner, building a primitive unit cell, and in addition to this translational symmetry only mirror symmetry in one direction is present.

If we look at this pattern over here, with these flowers as motif on a green background, we see a centered cell, again only combined with mirror symmetry in one direction.

This is different in this pattern over here, in which also a centered cell is present, but here vertical as well as horizontal mirror planes are present. And as we know from the past units, two mirror planes, which are perpendicular to each other do automatically generate a 2-fold axis of rotation.

Other patterns, for example, this one over here, show rotational symmetry of higher order - here a 6-fold rotational symmetry is present. This can be combined also with mirror symmetry as realized in this pattern. But if we look at this pattern here at the bottom right, then we see something - apart from the mirror symmetry - which we haven’t discussed so far. There are some parts of the motif, which show translation but they are not only translated but
simultaneously mirrored, when going from one motif to another.

It will turn out, that this symmetry relationship can be described with a so-called glide plane.

**Slide 4**

Let's approach the glide planes more rigorously. They are one of the 3 symmetry elements with a translational component.

Let's start again with a simple, pure translation operation, which you know already. Imagine: If we jumped barefooted on one leg on a beach we would see a repeating pattern like this. We can easily identify the unit cell and the translation operation. However, if we jumped like a kangaroo we would see a pattern like this - again a simple, repeating pattern, but now combined with mirror symmetry.

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But, if we promenade along the beach like a normal pedestrian - which is the more common way of walking - then we will see a pattern like this. And here we see on each side - so to say - the translations in amounts of whole unit cells, but in addition to that, these footprints on both sides are also symmetry related to each other. The whole pattern can be generated by applying a glide reflection - the respective symmetry element is called a glide plane or - because we are in 2D only - glide line.

This symmetry operation, the glide reflection, is a combined symmetry operation, in which two operations have to be carried out consecutively: first, a mirroring and then a translation, usually by one half of the unit cell constant. Such a glide plane is graphically marked with such a dashed line - and the character symbol is a 'g'.

**Slide 6**

Let's see the glide plane in action. First reflection, but this state is not realized, but further translated by one half of the unit cell, mirroring again, translation - and so on.

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Looking for other common objects, where we can find glide planes, we can think of - for instance - a rowing boat. Also some animals have fascinating markings on their skins, which have the symmetry of glide reflections. Look at this salamander called Kaiser's spotted newt - the white pattern on its back is related by a glide reflection but this fades into a pure mirrored translational symmetry at his tail.

Now, we know two of the three symmetry elements with translational components: pure
translations and glide planes.

In chapter 4, we will then discuss glide planes in crystals - there are some special features of glide planes in crystals in comparison to these glide planes in 2D... and we will get acquainted with the third symmetry element involving translations - the screw axes.

**Slide 8**

Okey, to recap - with the help of these 4 symmetry operations - Translation, Rotation, Reflection, and Glide - we are now able to generate all conceivable periodic patterns in 2D, which can be found for instance in wallpapers, textiles, tilings, pavements, gift wrap papers or even drawings of Maurits Cornelis Escher.

**Slide 9**

Only 17 principally different patterns exist and they are described through the 17 plane or wallpaper groups - they are based on the 5 two-dimensional Bravais lattices - I do not want to go through these here, but you can find them in the PDF of the slides.

**Slide 10**

[...]

**Slide 11**

As a last thing in this unit I want to briefly introduce the respective nomenclature of plane groups. In full length always 4 symbols are used for each plane group, p2mg is one example.

It begins always with a ‘p’ or ‘c’ to specify the lattice type, primitive or centered, and then 3 symmetry elements are specified.

The first one of the three denotes the highest order of rotational symmetry, here a two-fold rotational symmetry is present. And then two further symbols are given, indicating the symmetry elements in the two directions of the plane, first with respect to the x-, then to the y-axis. At the example there is a mirror plane with respect to the x-axis, and a glide plane with respect to the y-axis. If no symmetry element is present along these directions, we indicate this with a 1.

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Sometimes also a short notation is used: this short notation drops the rotational order or one of the mirrors, when they can be deduced by the presence of the given symmetry elements - and if this causes no confusion with another plane group symbol.

Here at the bottom all full and short notations are given. We know for instance, that two
perpendicular mirrors generate a 2-fold axis of rotation, so you can also leave this out.

And finally, to present a pattern which has indeed the symmetry ‘p2mg’ look at this pattern! Are you able to recognize the given symmetry elements?

As an optional assignment you could try to overlay this pattern with the respective graphical symbols of the symmetry elements at their correct positions within this pattern.