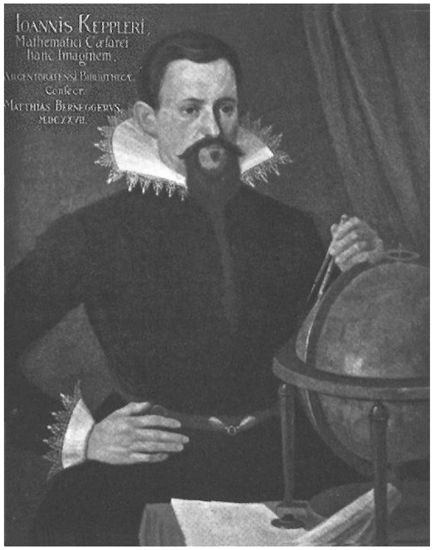
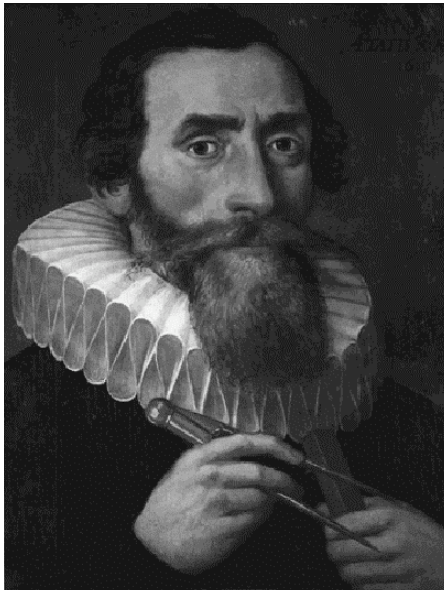
Crystal Magic. . .

by Ben "Rainbow Moonflower
Windsong" Waggoner

> Quartz crystals and gemstones easily attract all kinds of 'vibrations'; negative as well as positive. The stones are always 'open' to receiving impressions from everyone and everything around them! Your stone. . . may well have acquired many negative energies and ' vibrations' before it became yours. . . . You must do everything you possibly can to ensure that only the most natural - and purest - energies remain within your stone.
>
> **—some damn New Age Website. . .**

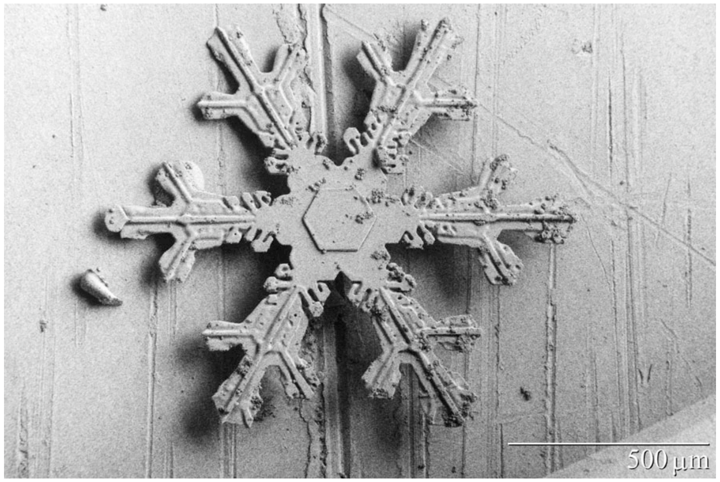


The *real* story started with a rather mystical guy himself, Johannes Kepler (1571-1630), who's more famous as an astronomer (he worked out the scientific laws that describe the orbits of planets around the Sun. . .)

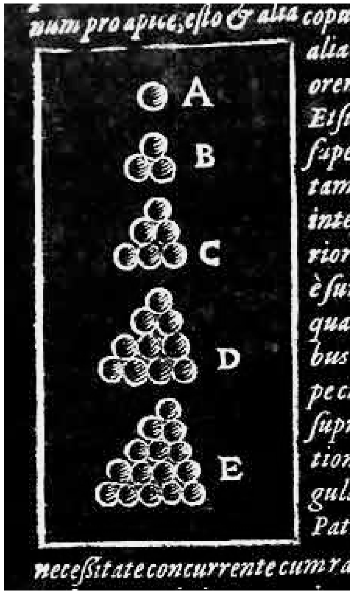


In 1611, Kepler published a little book called *A New Year's Gift; or, the Six-Cornered Snowflake*, and dedicated it to a friend of his, Matthaus Wäcker, who happened to be the treasurer of the Holy Roman Empire. . .

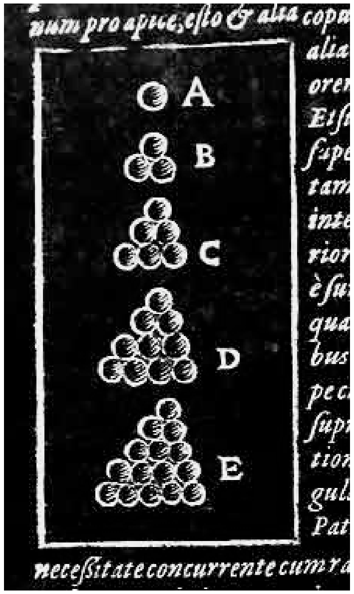
Kepler was curious about why snowflakes always seemed to have sixfold symmetry.

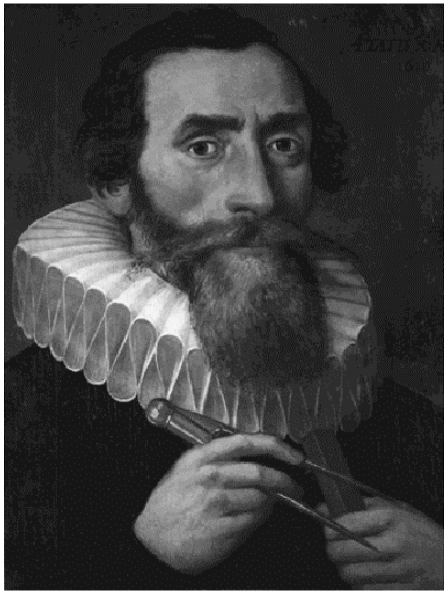


After thinking the matter over, Kepler argued that snowflakes had six sides because they were made of little spheres packed together. . . and that the tightest way to pack together spheres in a layer was in a hexagonal pattern, in which every sphere touches six others.



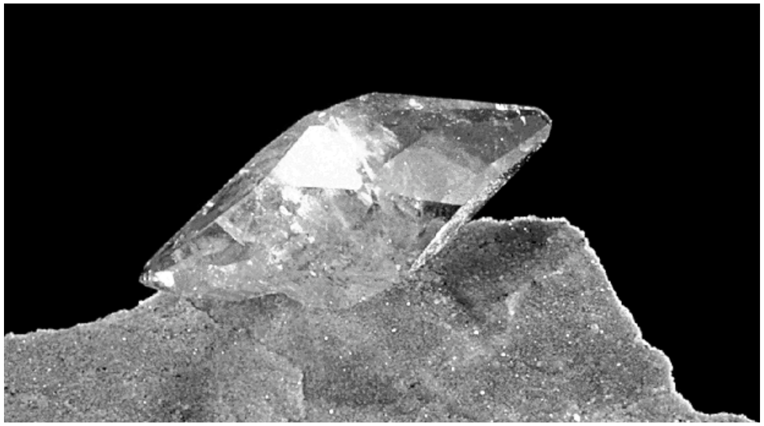
"The cause of the six-sided shape of a snowflake is none other than that of the ordered shapes of plants and of numerical constants; and since in them nothing occurs without supreme reason. . . I do not believe that even in a snowflake this ordered pattern exists at random." —Kepler, *The Six-Cornered Snowflake*

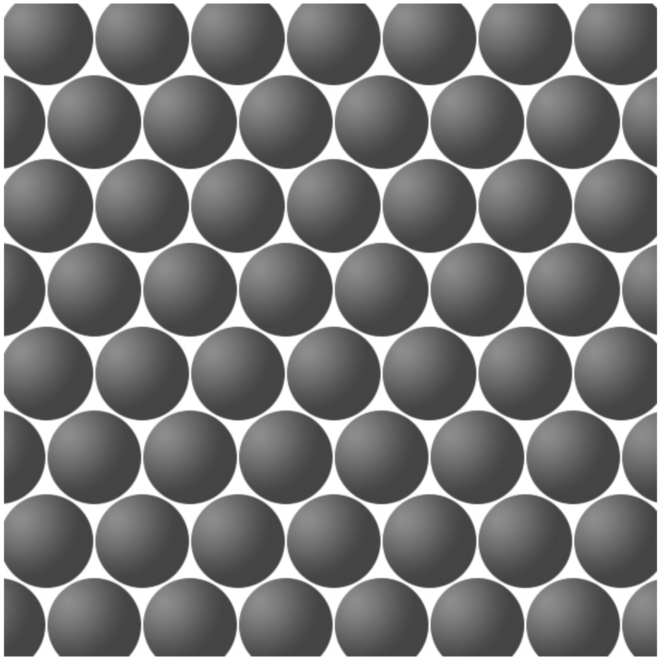




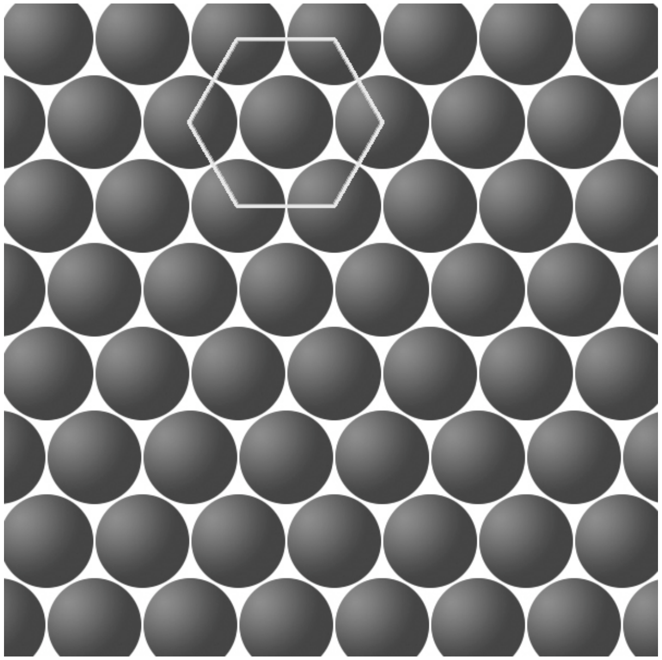
Some of Kepler's details weren't quite right, but he'd grasped something important: Atoms exist—and they pack together in regular, geometrical ways. Understand how they pack together. . .

. . . and you can understand why natural crystals look the way that they do.



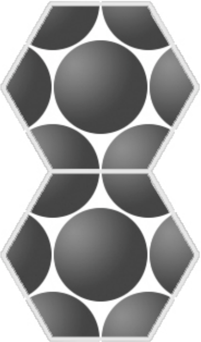


Begin by packing a group of spheres together in a single layer. Atoms aren't really spheres, but for our purposes we can pretend that they are.

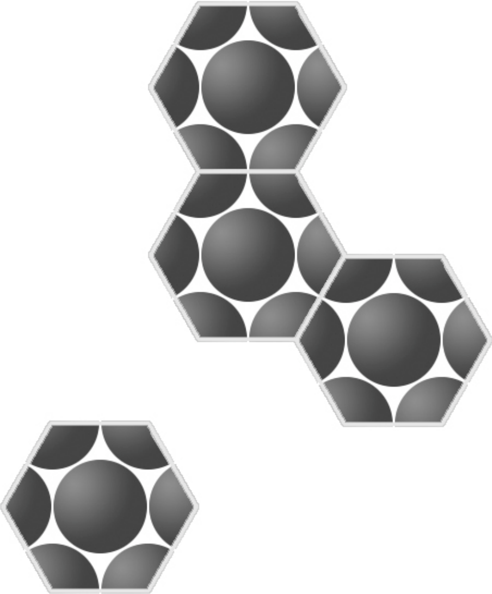


You can think of the packing as consisting of a number of hexagonal “tiles”. . .

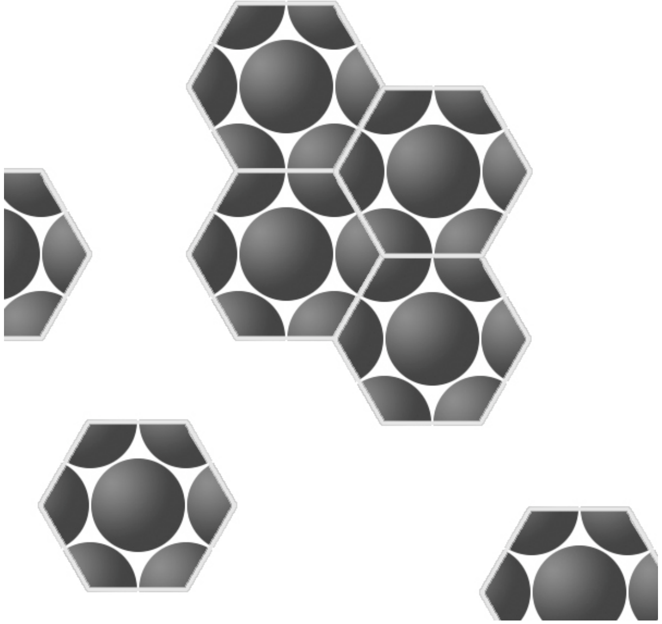
You can think of the packing as consisting of an infinite number of hexagonal “tiles”. . .



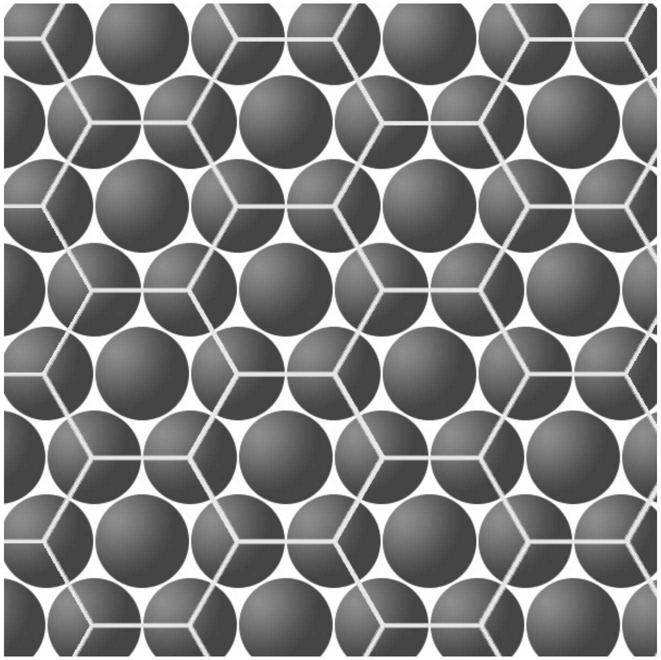
You can think of the packing as consisting of an infinite number of hexagonal “tiles”. . .



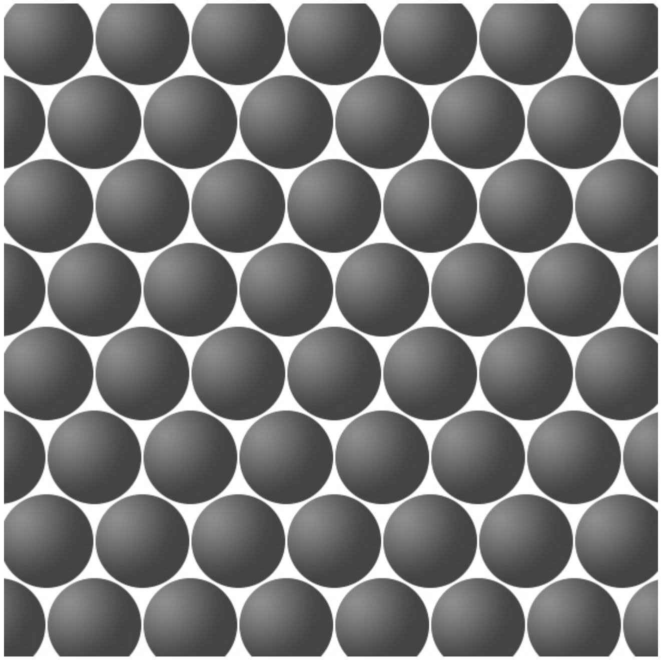
You can think of the packing as consisting of an infinite number of hexagonal “tiles”. . .



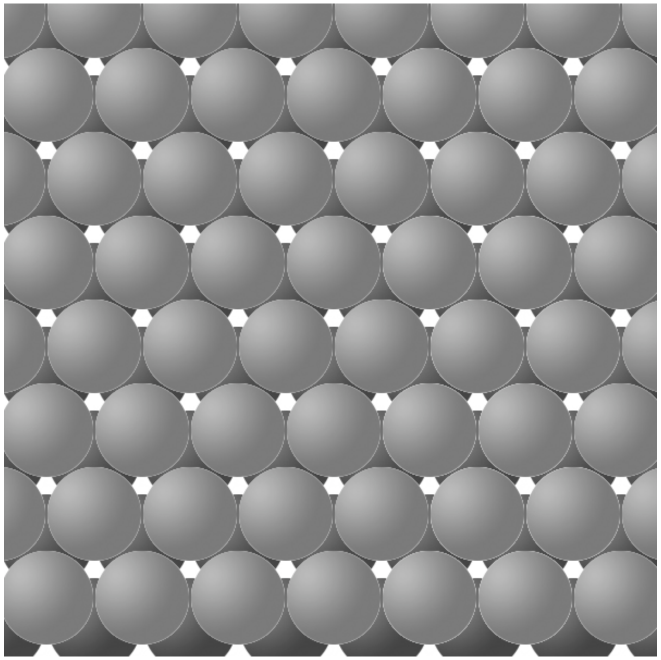
You can think of the packing as consisting of an infinite number of hexagonal “tiles”. . .



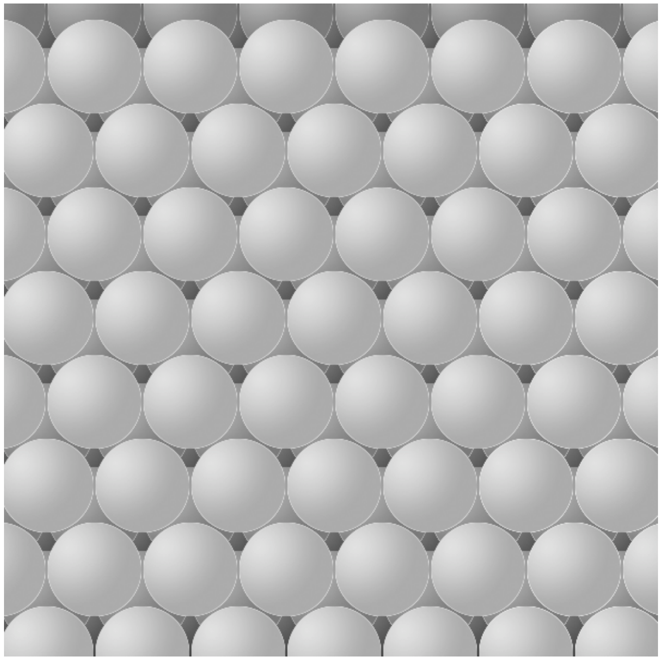
You can think of the packing as consisting of an infinite number of hexagonal “tiles”. . .



It gets trickier to show this in 3-D, but imagine starting with a layer of spheres. . .

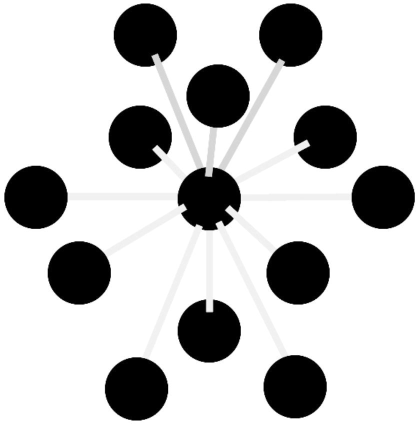


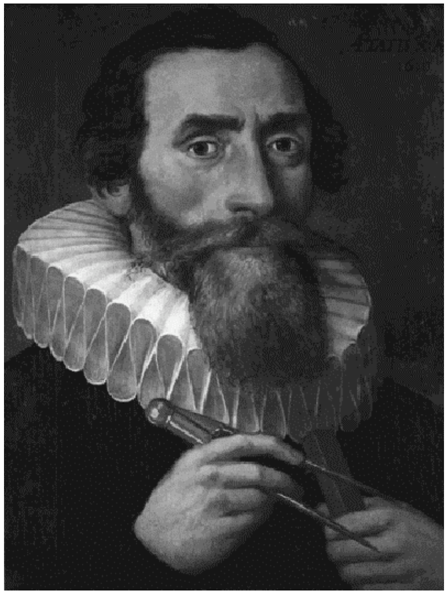
. . . and layering a second layer on top of the first. . .



. . . and a third layer on top of that.

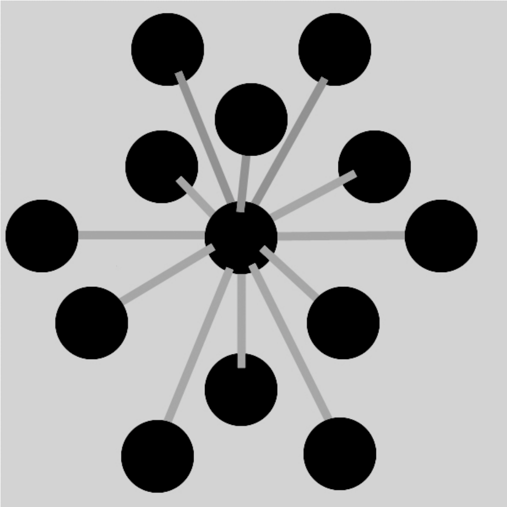
If we "explode" this packing for clarity, we see that every sphere touches six other spheres in its own layer, three spheres above it, and three spheres below it.



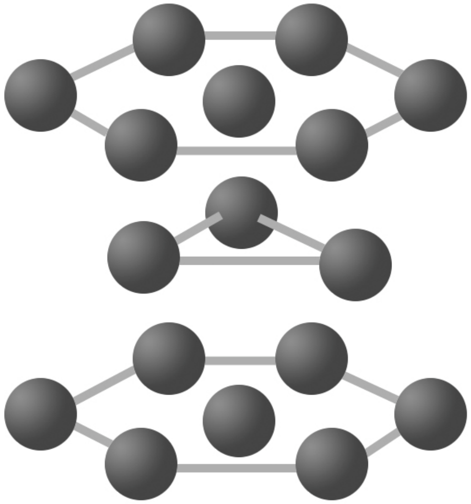


Spheres packed this way take up 74.05% of the available space. Incidentally, Kepler had said that this hexagonal packing is the tightest possible way to pack spheres. This idea, known as *<u>Kepler's Conjecture</u>*, was mathematically proved true, but not until 1998.

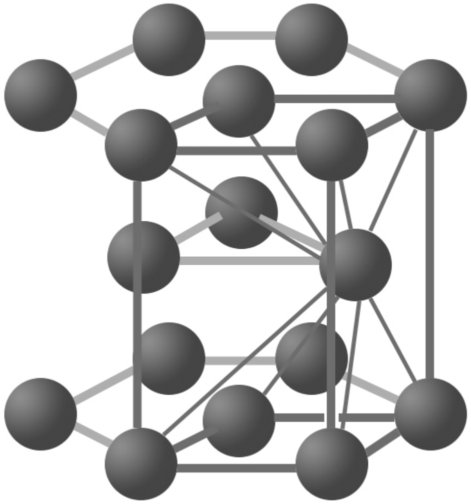
But even this isn’t the simplest description of hexagonal packing, because you can break it down further.



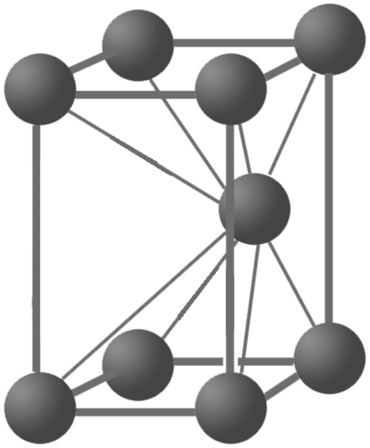
Let’s redraw this packing structure. . .



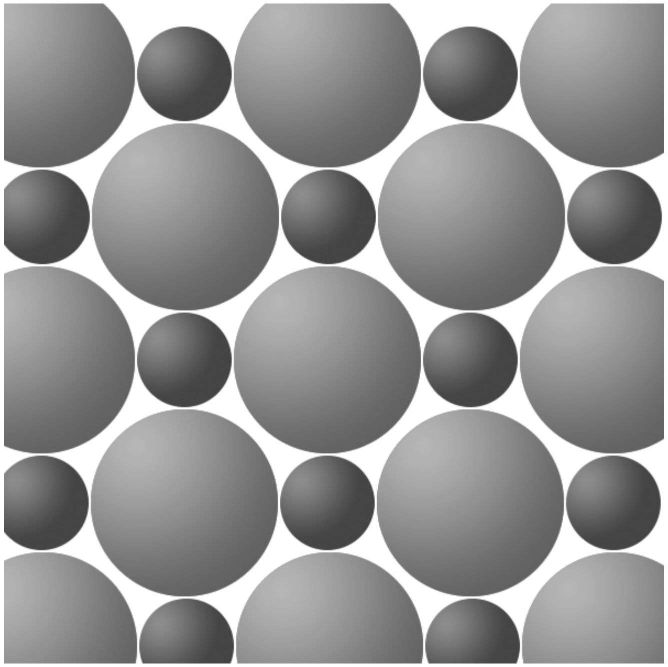
The red lines show the simplest repeating structure that exists in a hexagonal packing. . .



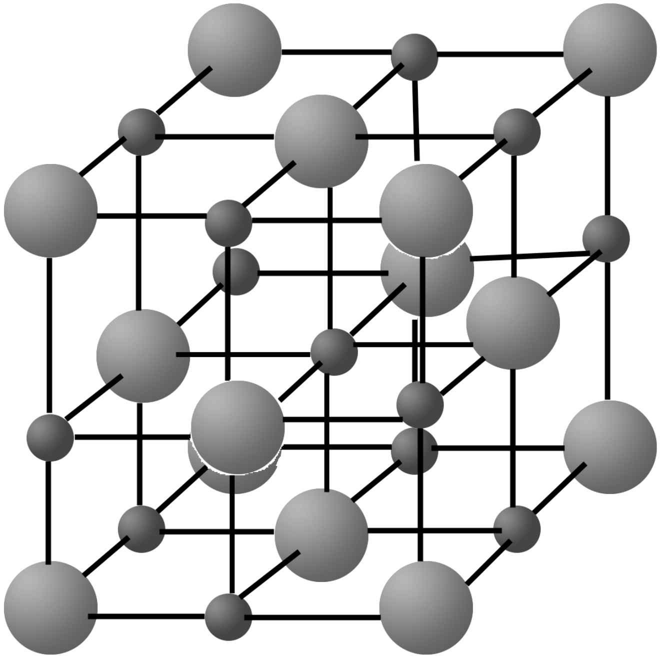
. . . this is the *unit cell* of a hexagonal packing.



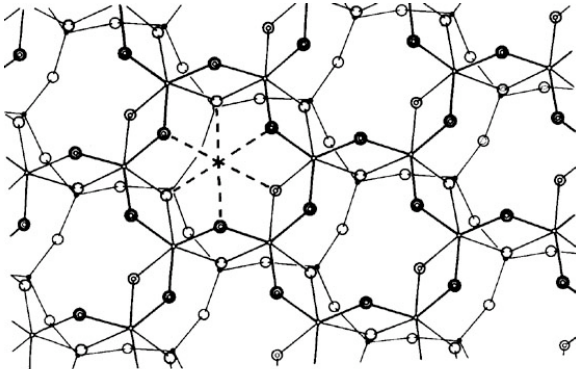
The same basic idea applies if you're packing spheres of different sizes, which may give you a *cubical packing*. . .



And this is how such atoms pack together in three dimensions.

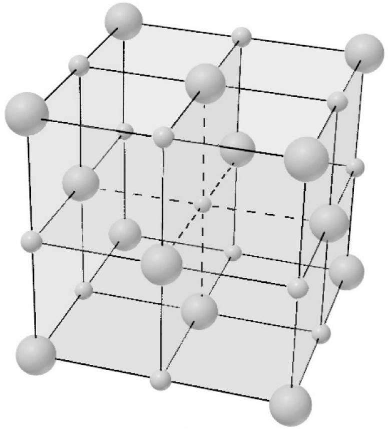


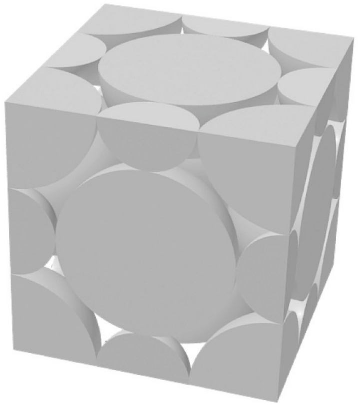
Things get more complicated when you have many different types of sphere, as in this diagram of a clay mineral's atomic structure. . .



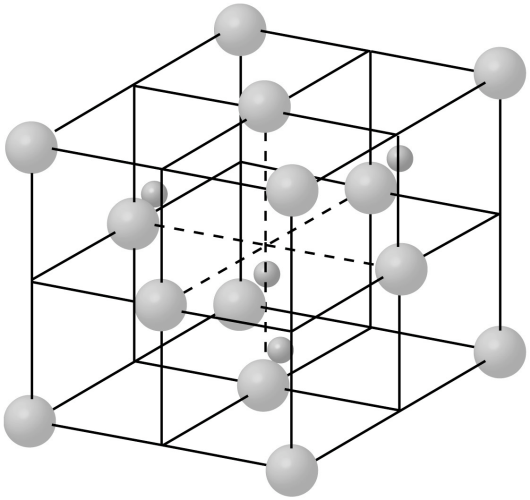
But it's still possible to define a unit cell, even if it's not obvious what that might look like.

Exactly what the unit cell looks like depends on the sizes and numbers of atoms and types of bonding. These diagrams show the unit cell of sodium chloride (NaCl), or *halite* (a.k.a. common table salt).

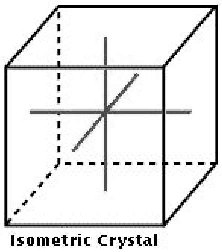




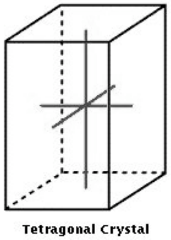
And here's the one for zinc sulfide (ZnS), or *sphalerite*.



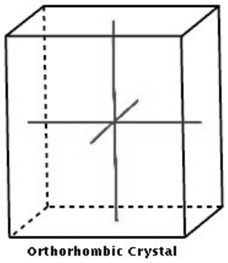
There are only six basic types of unit cell. . .



isometric / cubic (all sides equal, all right angles)

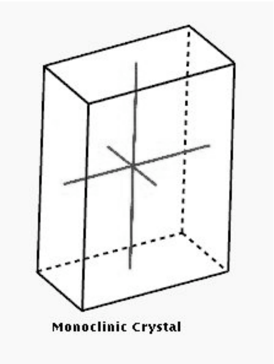


tetragonal (one unequal sides, all right angles)

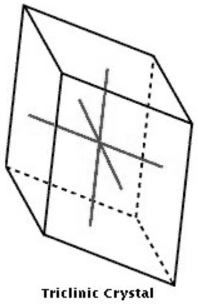


orthorhombic (all sides unequal, all right angles)

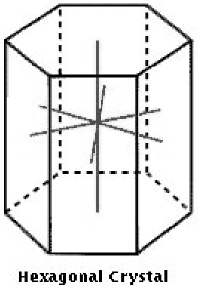
. . . and I'm not going to test you on the names, so don't worry about that for our purposes.



monoclinic (two angles not right angles)

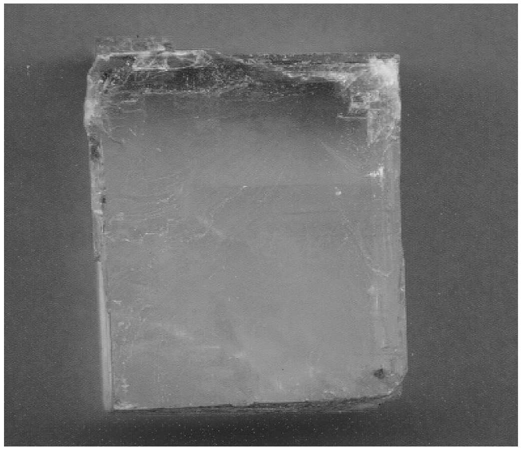


triclinic (no right angles)

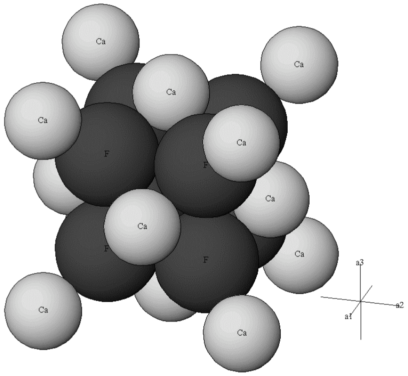


hexagonal

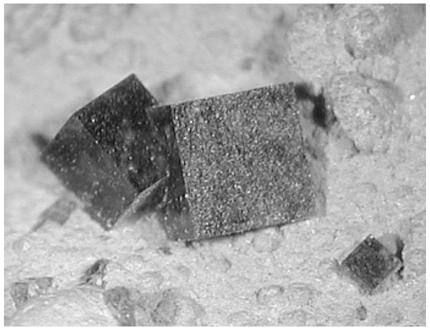
Sometimes, the shape of a crystal (its *crystal form*) is the same as the shape of its unit cell, as in this crystal of halite (rock salt).



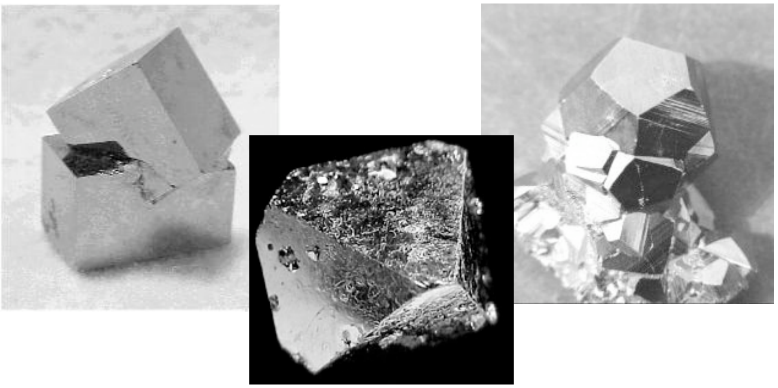
But unit cells may pack together in more than one way, and you can't always tell the unit cell by looking at the crystal form. Calcium fluoride, or *fluorite*, has a cubical unit cell. . .



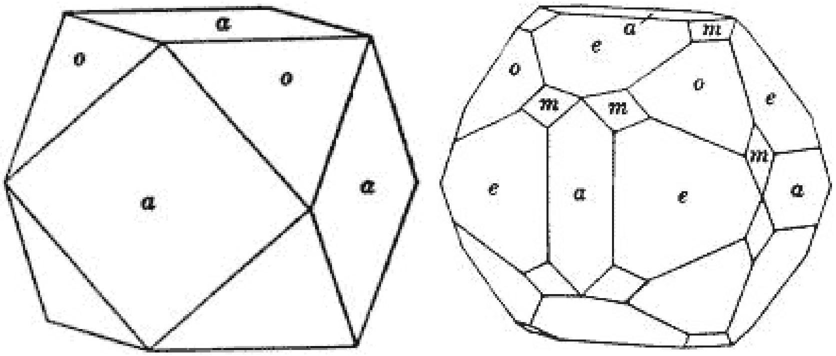
. . . but those cells may pack together in either cubes or in *octahedrons* (eight-sided crystals).



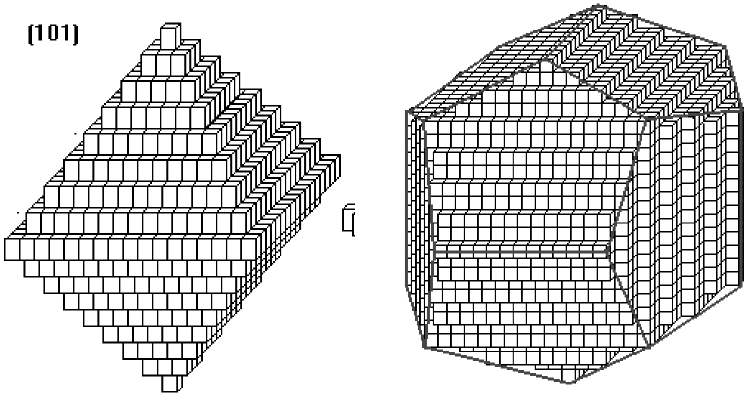
Pyrite (iron sulfide) also has a cubic unit cell, but the actual crystals may be cubes, octahedrons, or *dodecahedrons* (twelve-sided crystals), depending on how the unit cells are stacked.



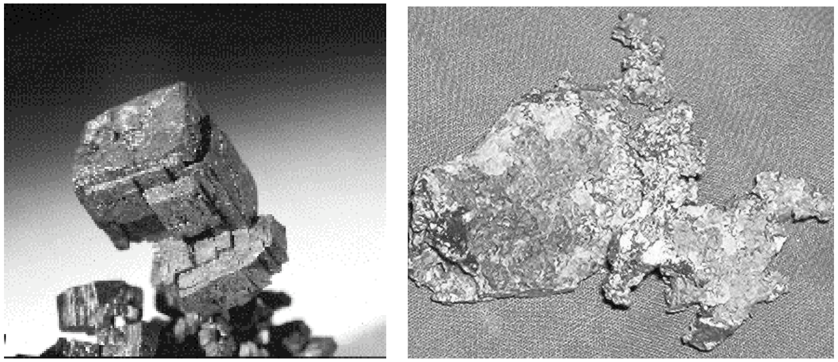
You can even get crystal shapes that are combinations of simple shapes—such as the “cube and octahedron balance” at left, or the “cube-octahedron-pyritohedron modified by trapezohedral facets” at right -- but let’s not get into that.



Instead, notice how cubical unit cells can pack together to give you a non-cubical crystal.

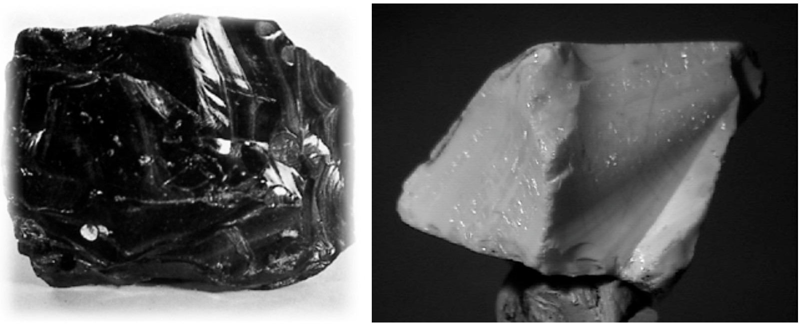


In other cases, a mineral may have a unit cell, but the cells may not pack together in any recognizable crystal form.



Copper, for instance, has a cubical unit cell and forms natural crystals (left), but often the crystals are too small to see (right).

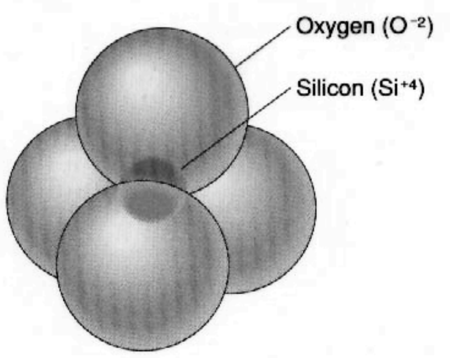
However, some substances, such as obsidian and opal, have no unit cells—the atoms are not packed in crystals at all.



Technically, these aren't minerals—a mineral is defined as having a repeating ordered structure, i.e. unit cells. Substances with no unit cell arrangement are called *mineraloids*.

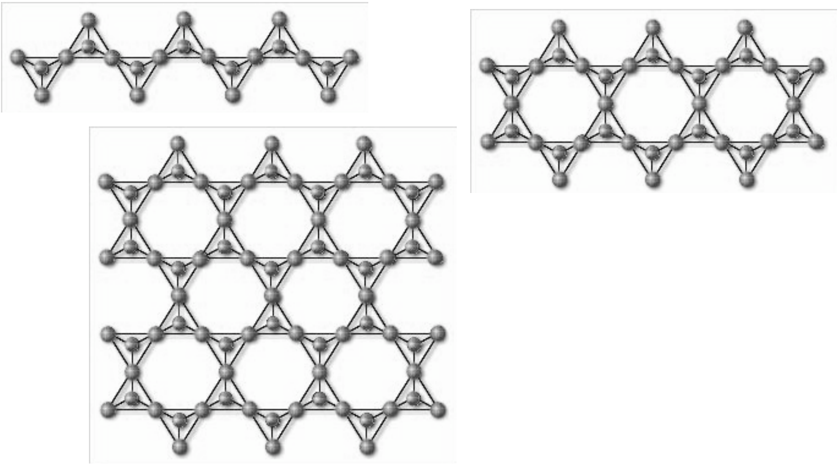
To tell what the unit cell actually is, it's usually necessary to use X-ray diffraction—firing a beam of X-rays into a crystal and observing the pattern of diffraction of the beam.

One important class of minerals, the *silicates,* is built around groups called *silicate tetrahedrons*. (Technically, these aren’t unit cells.)

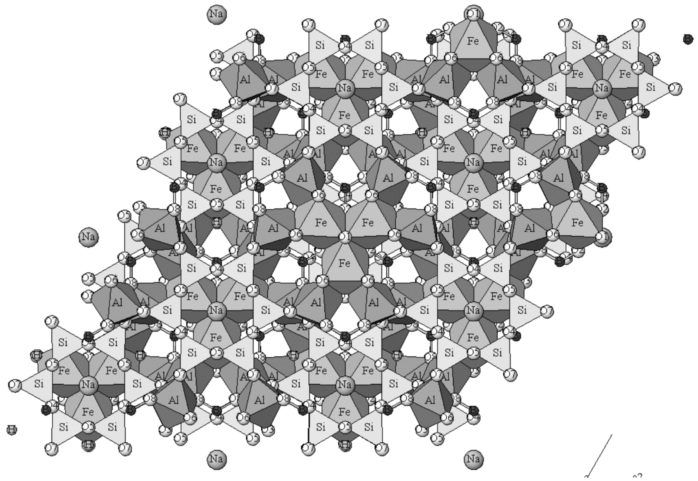


A Arrangement of atoms in silica tetrahedron

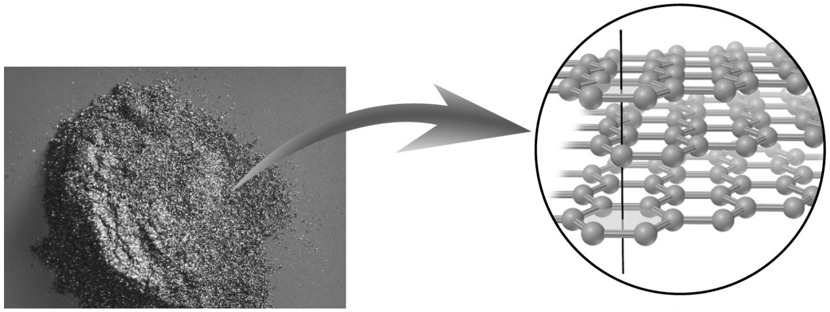
What makes these important is the fact that tetrahedra bond together at their corners to make chains, double chains, sheets. . .



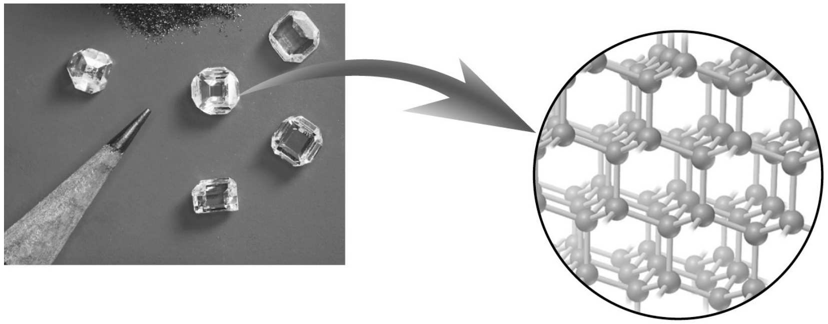
. . . or extremely complex *lattice* networks, as in this diagram of the mineral *tourmaline*.



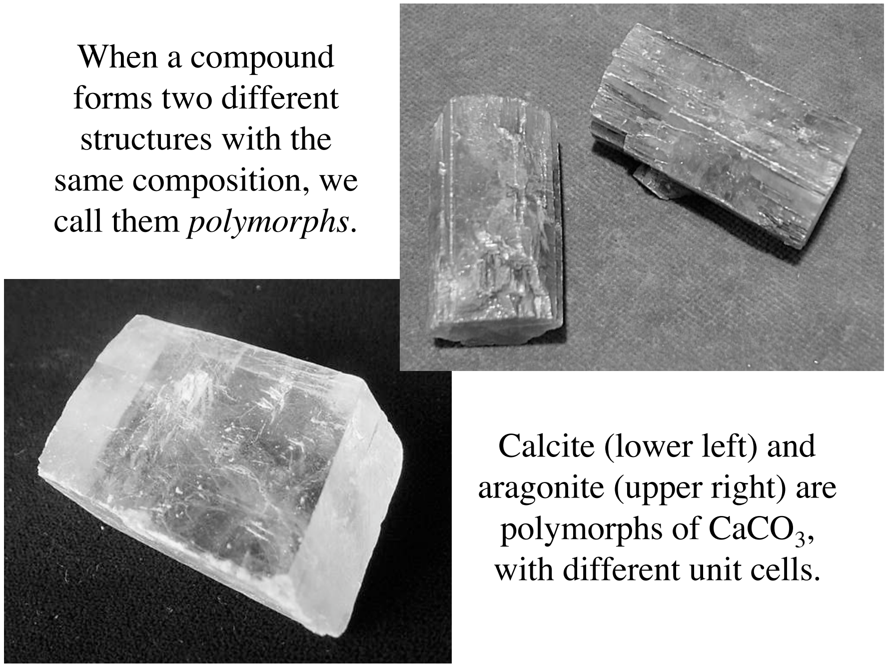
You can also get cases where the same atoms may pack together in more than one way. Pure carbon exists naturally in two forms: *graphite*. . .



. . . and *diamond*. When you have a single element that can form two crystal structures, we call those structures *allotropes*.



When a compound forms two different structures with the same composition, we call them *polymorphs*.



Calcite (lower left) and aragonite (upper right) are polymorphs of $CaCO_3$, with different unit cells.

So how do we identify minerals?

- chemical composition
- class of unit cell
- *crystal form* (shape of typical crystals)
- *cleavage* (natural way the mineral breaks)
- color
- density
- hardness
- other properties. . .