Electric current is moving charge. Magnetic fields are created by electric currents. The current creating the magnetic field could by the current in a wire or it could be the current created by the motion of electrons in atoms. In a permanent magnet, the electron currents in the atoms are aligned so that the net effect of all the microscopic electron currents is to make a macroscopic current which is just like the current in a solenoid. So you should think of a bar magnet as a bar-shaped solenoid of current. The magnetic field of a bar magnet is exactly the same as the magnetic field of a solenoid since the currents are the same.

**B-field due to a solenoid.** solenoid = cylindrical coil of wire

It is possible to make a uniform, constant B-field with a solenoid. In the limit that the solenoid is very long, the B-field inside is uniform and the B-field outside is virtually zero.

I

I

B

End View:

I

**B** uniform

inside

Side View

L

**B** nearly uniform inside

I(out)

I(in)

**Permanent Magnets**

Currents make B-fields. So where's the current in a permanent magnet (like a compass needle)? An atom consists of an electron orbiting the nucleus. The electron is a moving charge, forming a tiny current loop –– an "atomic current". In most metals, the atomic currents of different atoms have random orientations, so there is no net current, no B-field.

In *ferromagnetic* materials (Fe, Ni, Cr, some alloys containing these), the atomic currents can all line up to produce a large net current.

atoms

**cross-section of**

**magnetized iron bar**

In interior, atomic currents cancel:

net I = 0

on rim, currents all in same direction, currents add

In a magnetized iron bar, all the atomic currents are aligned, resulting in a large net current around the rim of the bar. The current in the iron bar then acts like a solenoid, producing a uniform B-field inside:

net atomic current on rim

uniform

B(out)

atomic current on rim,

like solenoid

**Side View:**

**End View:**

**N**

**S**

B-field comes

out of "North" end

B-field enters

"South" end

Why do permanent magnets sometimes attract and sometimes repel? Because parallel currents attract and anti-parallel current repel.

**N**

**S**

**N**

**S**

parallel currents on ends attract

opposite poles attract :

**N**

**S**

**N**

**S**

like poles repel :

anti-parallel currents

on ends repel