I
CURRENT

The flow of electric charge (units of "coulombs") is called current (units of "amperes", or "amps," which is coulombs per second). Current typically flows through *conductors*, materials that have a lot of free electrons. It's hard for current to flow through *insulators*, or materials without a lot of free electrons. "Free electrons" are not truly free: they are very loosely bound to an atom, versus some electrons, which are tightly bound. There are a lot of balancing forces going on in the atom, but generally, when atoms have "full" outer shells, it's harder for an electron to separate out from the atom.

One example of a good conductor is copper, which your house wiring is likely made of. Copper is a good facilitator of electron movement because there's one electron in its outer shell, which makes it easier for that electron to detach from the atom and move to another atom's outer electron shell. This movement of electrons is considered current. Insulators, like wood, rubber, or plastic, are poor conductors because the electrons in their outer shell are tightly bound - there's not just one free-roaming electron like with copper. Conductivity decreases as the number of electrons in this outer shell increase.

Now, there must be initial energy for this movement to take place - and that comes from the force called *voltage*. If the voltage is high enough, electrons *can* be split off from an outer shell of the atoms within an insulator (which is why you shouldn't use rubber cleaning gloves to do electrical work!). We'll get to voltage in another section. For now, let's focus on the fact that electrons are moving around.

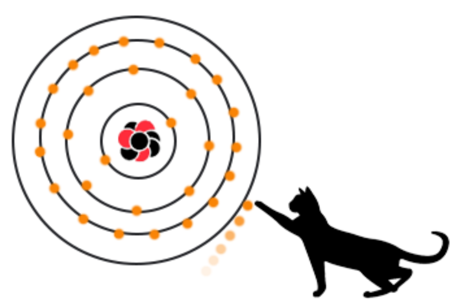

FIG. ii Copper atoms (nucleus not to scale) only have one electron in the outer "shell", meaning it is easier for this particle to separate from the atom and move, transferring energy. This atom is becoming a *cation* (pun intended) due to its overall positive charge from removing an electron.

If no external electrical force is applied to a conductor, these electrons kinda mosey about randomly from atom to atom. When a voltage is applied, energy is provided for electrons to move in a particular direction, inducing current flow. Current flow happens in power lines at *nearly* the speed of light - but the electrons themselves are *not* flying at the speed of light! What's actually going on is that energy is transferred very fast through the wire, but the electrons themselves are vehicles to transfer energy from atom to atom. Generally, there is some energy loss that occurs as electrons bump into other atoms as they move through a conductor. In copper wires, these are our heat losses. You may have heard of “superconductors” - these are conductors which have no losses - electrons move without bumping into atoms and losing energy.

The “flow of electric charge.” Technically, current can be the flow of protons *or* electrons (or even other charged particles). In fact, the direction of current flow is actually defined as the direction of the flow of *positive* charge, as this was the convention chosen in the early stages of understanding. However, in most cases, and particularly in metals, electricity is the flow of electrons. Check out the image of an atom in Fig. i or Fig. ii. Electrons are moving around in a cloud around the nucleus, whereas the protons of an atom are *inside* the nucleus, tightly bound to the neutrons. Protons are also 2000x more massive than electrons. Thus, it is significantly easier for the electrons to be the ones moving about in a conductor.

The “source” of electrons. Note that power plants don’t “supply electrons” - all of the current flowing in a power line or copper wire is made up of the electrons in that wire itself. The power plants just provide the energy needed to move the electrons that are already in that conductor. This means that, theoretically, copper (or aluminum, which is used for power lines) wiring can last forever and not degrade in its ability to conduct electricity. However, if the wire heats up too much, to the point where the wire melts and changes shape, it can change the ability of the wire to conduct current at the same levels. This is why we try not to push too much current through wires that are not big enough to carry those charged particles - because then the wires heat up (due to crowding from more electrons bumping into atoms) and become damaged. For example, if you have a copper wire in your house that was sized to carry 15 amps and you try to plug in a device that consumes 16 amps, your breaker should flip and disconnect the circuit to prevent the wire from heating up too much. Power lines in particular can heat up to the point of sagging and touching things like trees, which can cause short circuits.

Deadly current. The units of electric current are typically given in amperes, or *amps*. The level of current that a common hairdryer uses is around 15 amps. The level of current that can stop a human heart is around 0.2 amps. You may already know that our brain, heart, and nervous system work off of electrical signals - these are not the flow of electrons, like in a metal. The “electricity” in your body is from the flow of ions, not simply electrons.