# "Home Grown Circuits"

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How do we make an electronic circuit? The answer has changed quite a few times in our century-old circuitry industry. The first circuits weren't even printed; they were made by cutting strips of metal and creating the pattern by gluing pieces to a dielectric. Later on, circuits were formed by printing metal-filled conductive pastes that were thermally hardened and had to be quickly plated up before the conductive ink oxidized. Still later, we borrowed from the printing plate fabricators and adopted subtractive etching, a process that is still the mainstay, but giving ground to additive processes. Semi-additive methods are gaining, especially in the flexible circuit arena where thin adhesiveless copper flex materials are easily masked, plated up with copper, and the "seed" layer of thin background copper is finally etched away to make high-density circuits. Ink jetting concepts are being embraced again after failing to gain much traction a few decades ago. Even embossing and groove circuit concepts are getting a modern spin under micro- or nano-imprinting monikers. So how will we make circuits in the slightly more distant future?

How about growing circuits? Why not bio-crafted circuits, an idea that's been around for a long time! The bio-circuit concept will almost certainly be resurrected as the nanotechnologists begrudgingly recognize that biology (and chemistry) are components of nano-science. Biology and chemistry principles operated during assembly of complex nanostructures involving self-assembly long before the nanotech term even came about. In fact, chemistry operates at sub-nanoscale (Angstromology?) and biological systems have been self-assembling before man ever walked the earth. We sometimes get caught up in our technology and overlook that we mostly imitate nature, and often poorly. As the song writer warned, "Don't let the sound of your own wheels make you crazy". And that should apply to nano-wheels, too. But can we really expect to grow circuits in the future? Of course, and there is already a precedence set. The brain, with the most wonderful and complex circuitry, is self-assembled and bio-crafted in an orderly manufacturing process adhering to the principles of science. And it's a 3D neural network.

So when might we tap into this wonder science and magic? Where would we even start? Do we want electrical pathways - or something else? Electrons are pretty good messengers, but photons beat them by a million-to-one and the Internet wouldn't be practical without photonics. Maybe the architecture should mimic the brain's. But who really knows how the brain works with its ions, chemicals and neurons in an environment that contains water and salt? Your brain may have as many as 100-billion neurons and they are interconnected, so that's a lot of circuitry with trillions of connections. By the way, you are losing about one neuron each second, and that's without even drinking, so don't postpone working on great ideas too long. There's no comfort in the fact that you once grew neurons at the rate of 12-million per second in your prime, before you were born.

What kind of bioprocess would work best? Should we try to construct molecules to serve as nano-robots to move atoms into place, in a "bottom up" Drexlerian process? DNA could perhaps assemble carbon structures such as Carbon Nanotubes (CNT) or wires. Or should the bio-structures themselves become circuitry? We might assemble molecules with the desired angles like so much nano-plumbing, a half-century old idea. Perhaps the circuits themselves will be the active devices in a highly integrated organic system. DNA is the most complex molecule known and may contain 1-million pages of coded information. It is one wondrous polymer. So maybe our bio-circuits will grow the network, the devices and the embedded software. We evidently start off with a BIOS self-booting system at birth, right? And maybe, like the brain, the circuit system will be programmed to some extent through teaching.

While an electron-conveying circuit scheme is possible, it’s not essential in the bio-linked arena. The information carrier may be ions or chemicals and the logic scheme may be so powerful that we don’t need fast streams of digital signals. Advanced systems of the future may even be analog or a mixed hybrid. The brain is much more complex than simple digital and binary, and massively parallel. Our new bio-centric thinking machines may be so massively parallel that clock cycle and frequency are obsolete terms from the old copper-epoxy 21st century. EEG scans show brain frequencies of no more than 30 Hz. That rate is much slower than the original IBM PC, but the brain is infinitely more powerful when fairly measured against any man-made “brain”. What about board assembly, if such a term is still used?  Solder would almost certainly be obsolete since the devices would be grown into place. The system would be lead-free and maybe even metal-free, but might contain halogens, the elements essential to life.

If biocircuits were to become the norm, how would we prepare for circuitry of the 22nd century? Study biology, nanotech, chemistry or something totally new since it seems certain that circuitry will move to an organic basis in the future? And who will manufacture biocircuitry-based systems of the future? Probably the systems themselves.