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Biomimetic Manufacturing

Next generation manufacturing innovation will be enabled by imitating biological systems in production environments. This white paper motivates new research in this biomimetic manufacturing arena through several examples. The expectation is that these illustrations will spawn follow-on discussions and a fundamental new direction in manufacturing research.

Tree growth New growth occurs only in limited locations on a tree, referred to as meristems[1]. The associated cell division increases the length and diameter of buds, which appear at twig tips. This leads to the familiar growth rings that can be observed in the cross-section of a tree's trunk. It is interesting that tree growth does not occur in layers and yields a natural question: *should additive manufacturing proceed in layers or could other approaches be applied that mimic tree growth? Are other addition (growth) strategies available that could increase isotropy, strength, fatigue life, or surface quality?*

Beaver teeth Beaver incisors are self-sharpening. The outer surface is composed of hard enamel, while the inner portion is made of much softer dentin. As the dentin quickly wears, the cutting edge remains sharp. The tooth also continuously grows, which compensates for the high dentin wear rate. The research question is: *could cutting tool designs evolve to accommodate, rather than minimize, wear and subsequently improve machining productivity? Instead of new coating technology, could new designs "grow" at an appropriate rate and self-sharpen using the hard/soft layer paradigm?*

Beans Beans sprout when water dissolves the hard seed casing. After the casing splits, the roots emerge first as they unfurl from the seed. The next stage is leaf growth; a pair of leaves unwrap from the beam stem as shown in the figure[2]. The manufacturing question is: *could new materials and designs be created that enable parts to be produced monolithically and then deployed, rather than manufactured, assembled, folded, and then deployed?*

Termites Termite behavior includes: communication by vibrations; and swarming to produce a new colony. They also have protozoa and bacteria to produce enzymes that break down wood cellulose into sugars they can digest[3]. In an alternative to current material removal processes, *can this behavior be adapted to enable massively parallel material removal using small, autonomous robots that "digest" the workpiece and are collectively controlled using swarm principles?*

Education The intersection of manufacturing science and biology will promote cross-pollination of these two disparate disciplines. A clear advantage (beyond the natural synergy to be gained) is that biological programs are typically more diverse than manufacturing with a much higher percentage of female students. This will provide a much-needed step change in manufacturing research participation by under-represented groups and will, therefore, inherently lead to innovation through increased diversity.

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[1] http://dendro.cnre.vt.edu/forsite/howdoes.htm
[2] http://garden.lovetoknow.com/image/138556~lifecyclebeanplant.jpg
[3] https://www.termites.com/information/facts/biological-traits-of-a-termite/