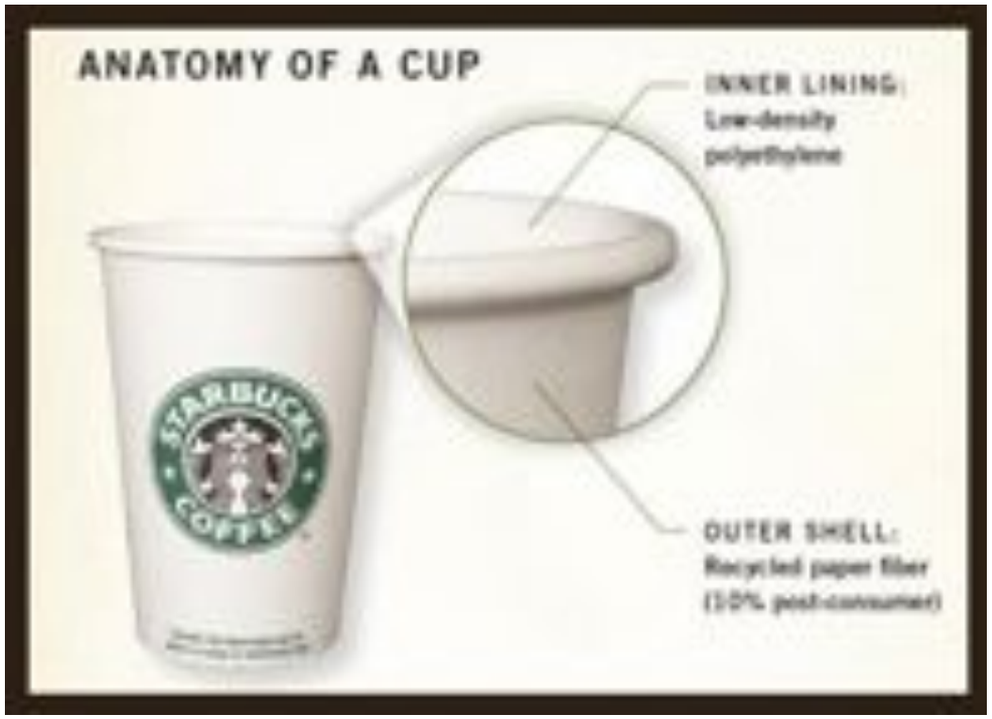
Programming Biology

1. Natural computing
2. DNA code
3. Bringing biology and computing together

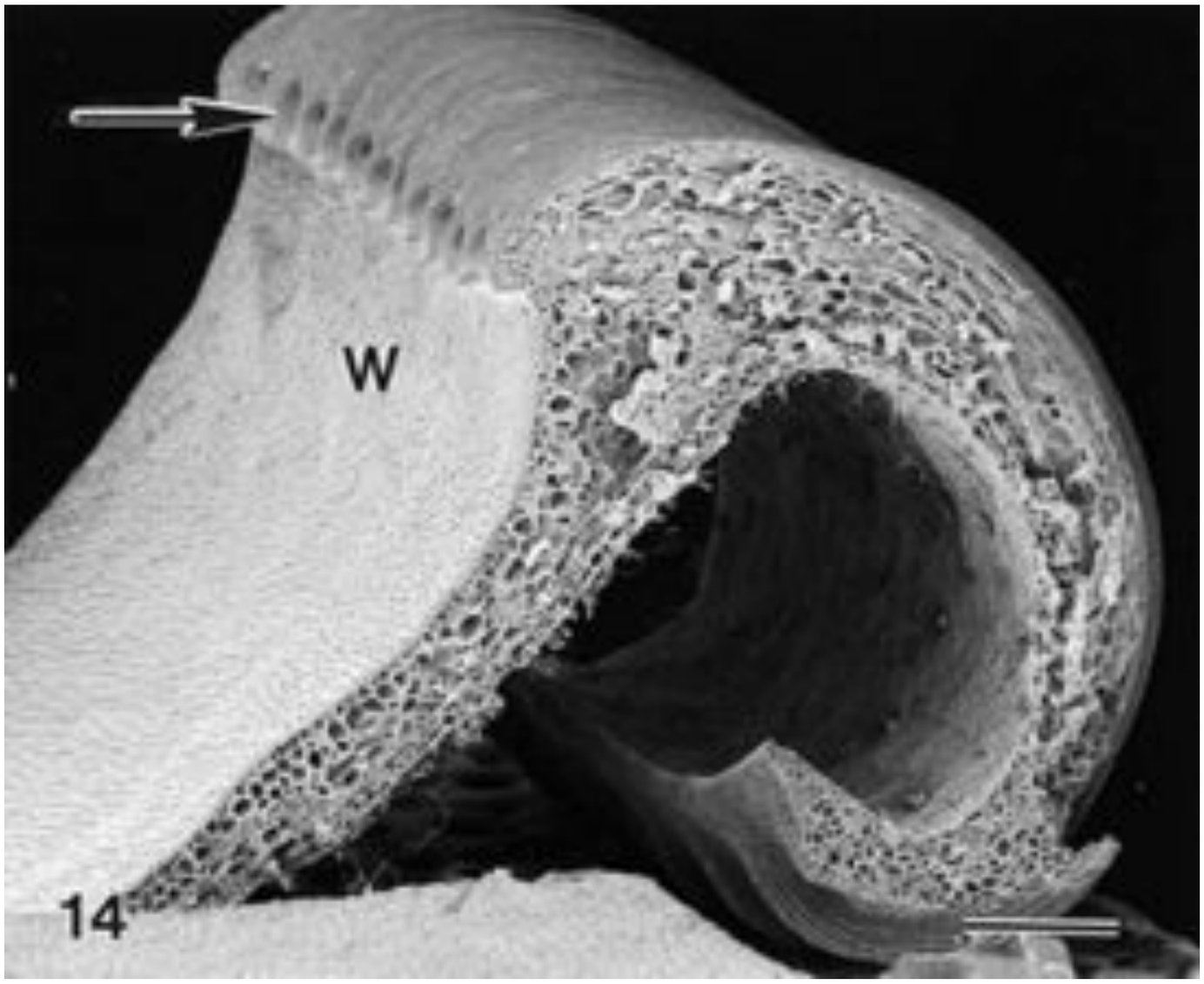
Jim Haseloff
University of Cambridge
www.haseloff-lab.org

BBC Natural History Unit


CAUTION: HOT
Sugar
Milk
Cream
Decaf

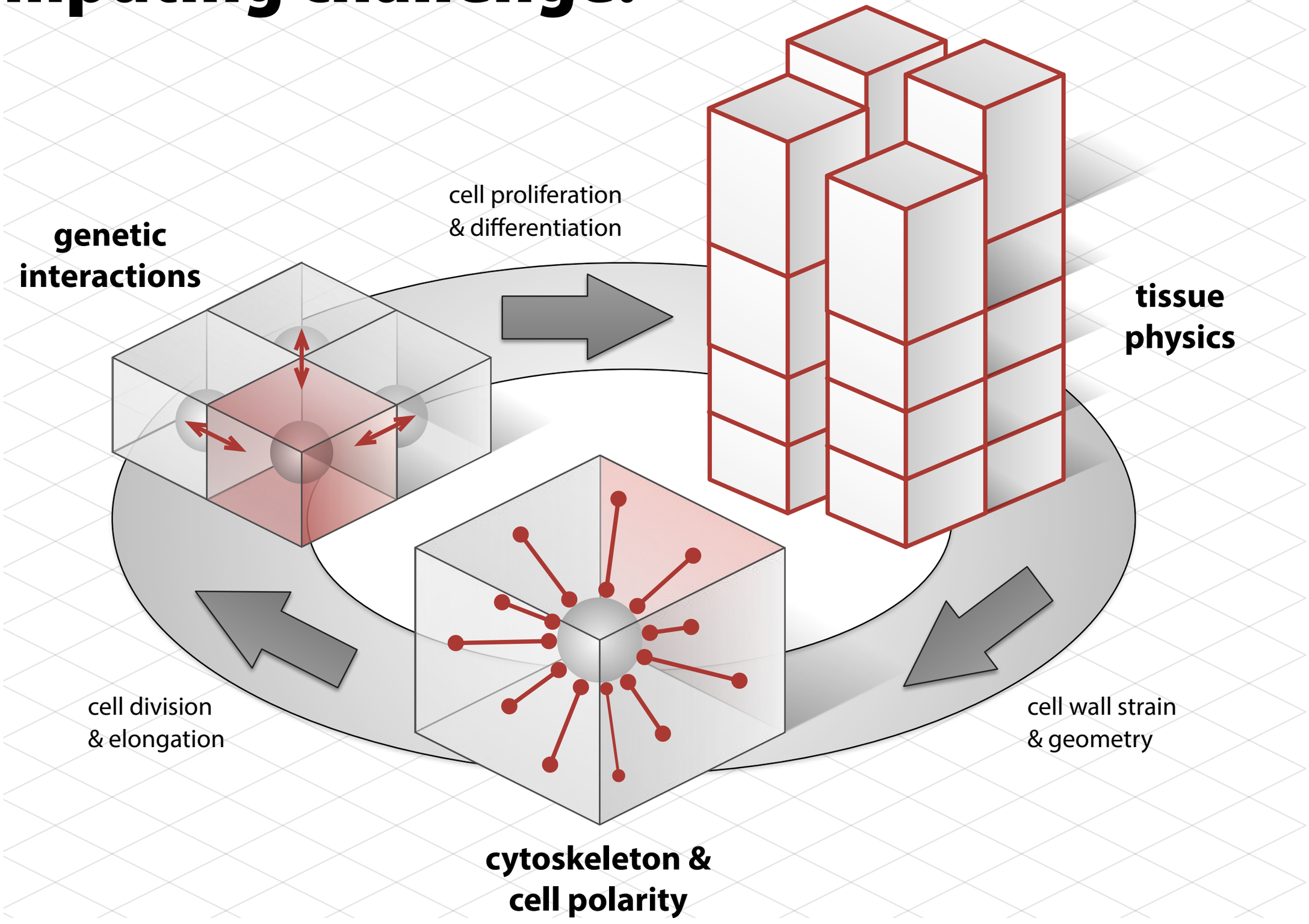


paper cup

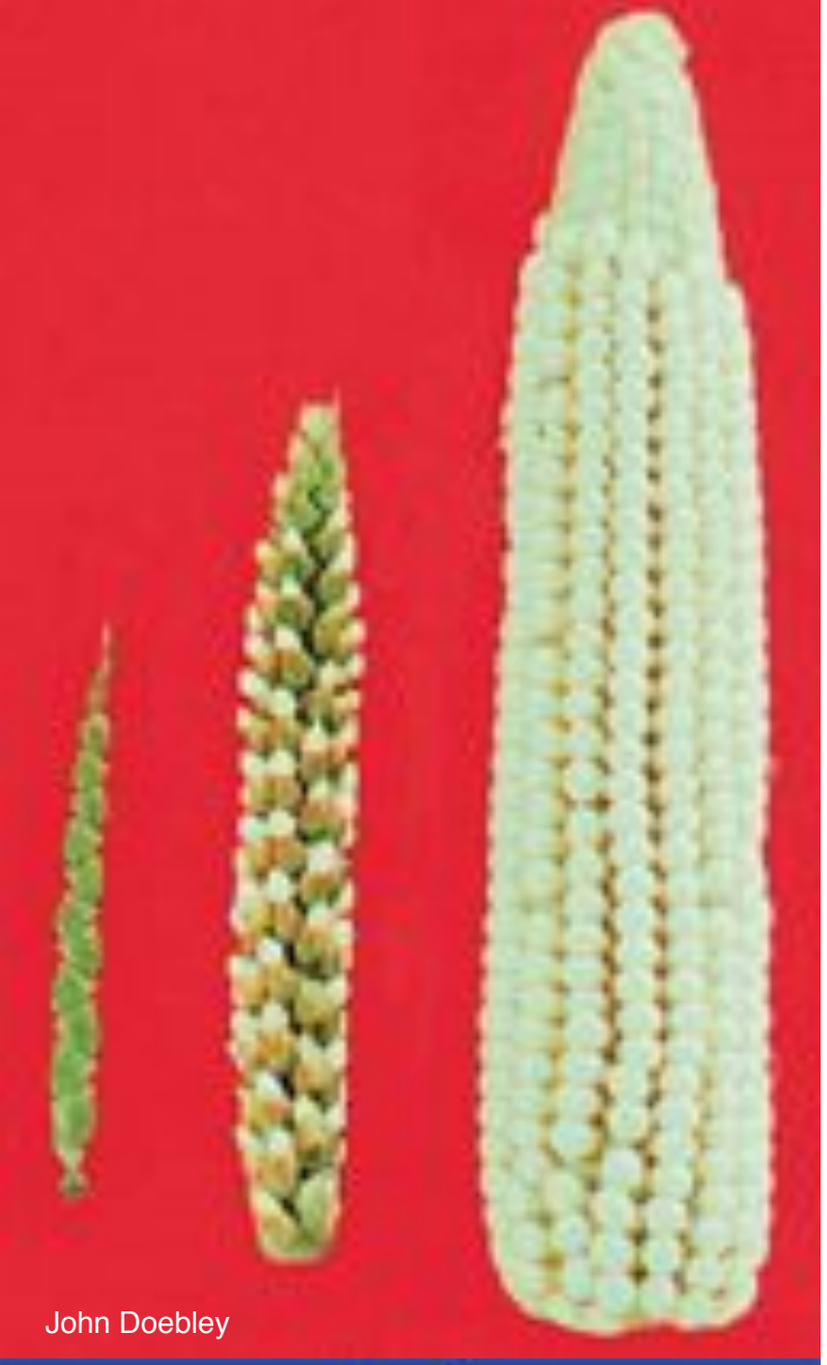


pitcher plant

Computing challenge:



Multiscale models for cellular growth

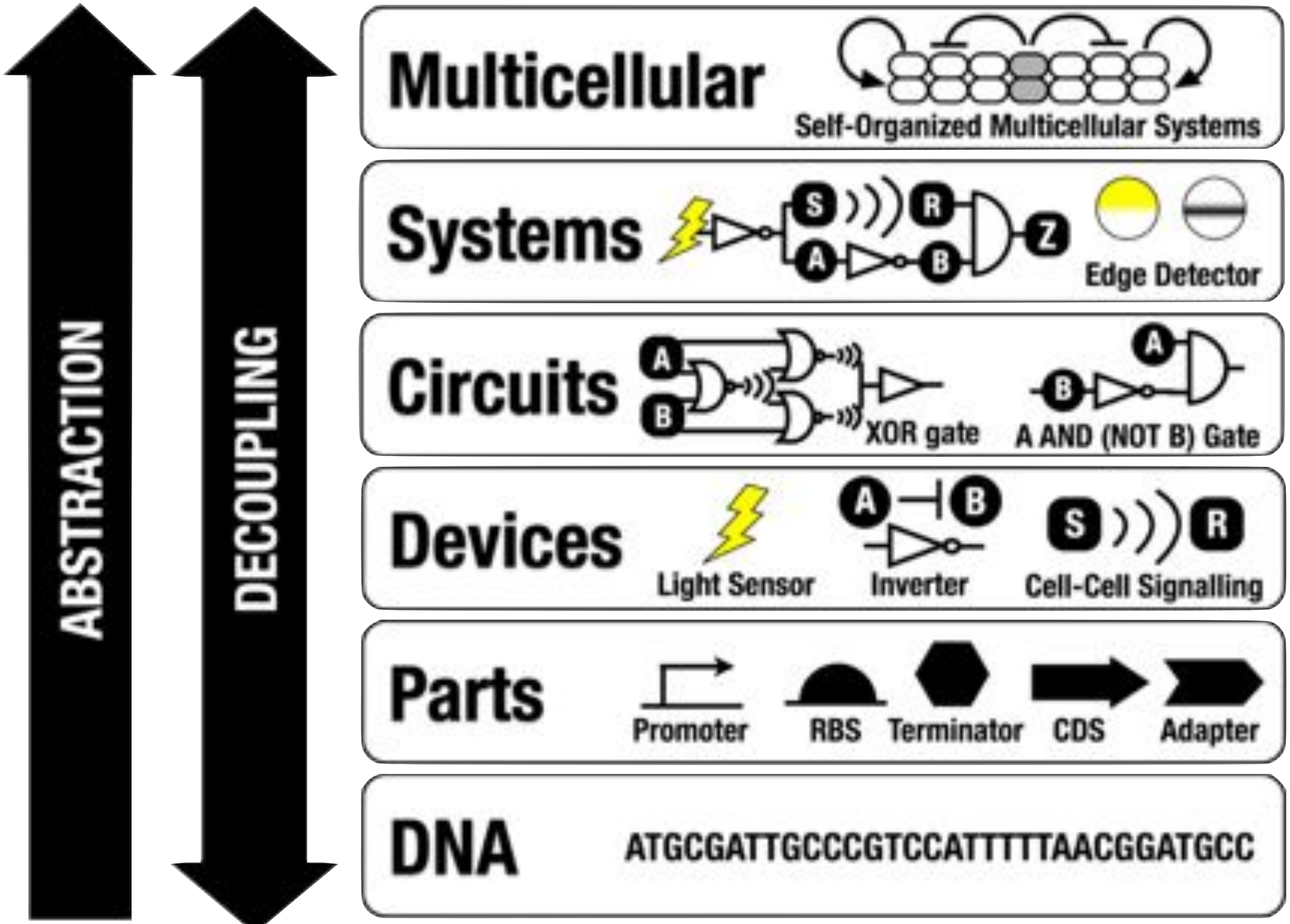


John Doebley

Reprogramming plants

- Biological systems underpin future sustainable approaches to production and remediation
- Plants provide proven, global, low-cost technology for gigatonne scale bioproduction
- Plant systems are highly plastic, and Synthetic Biology offers breakout technologies for reprogramming form and function

DNA code: modular parts and assembly



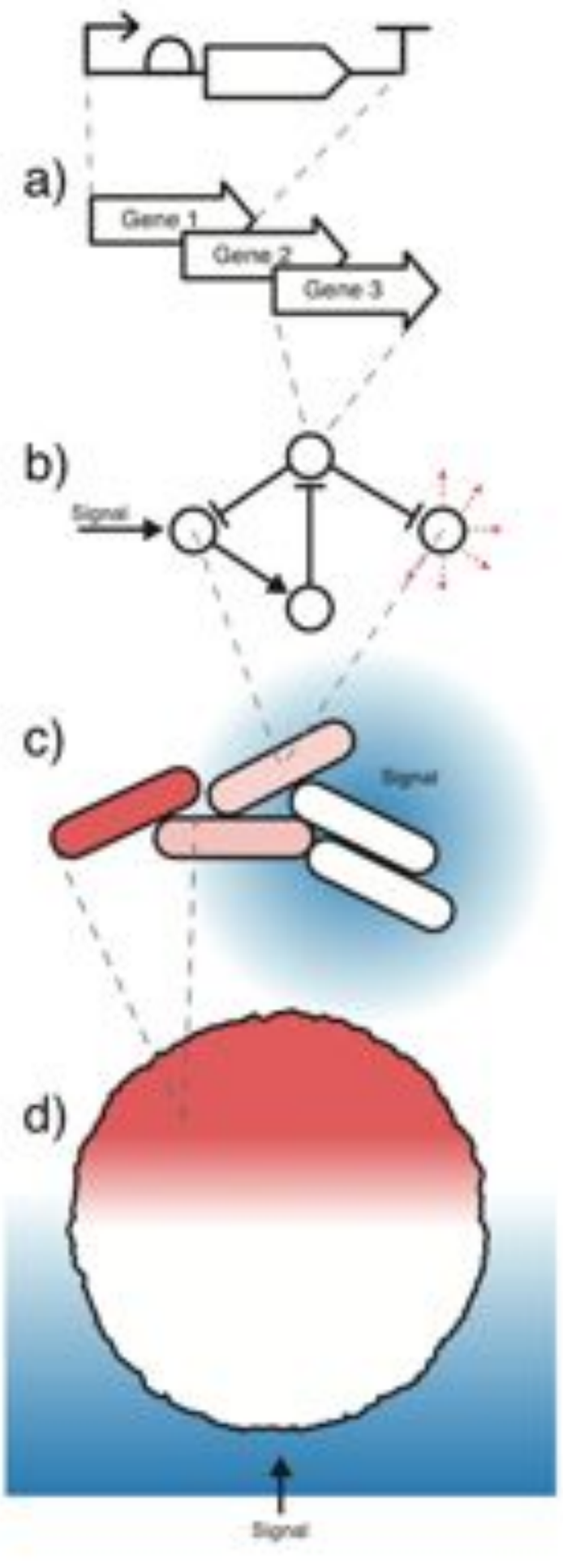
Federici, Rudge, Pollak, Haseloff, Gutierrez, 2013

Scale

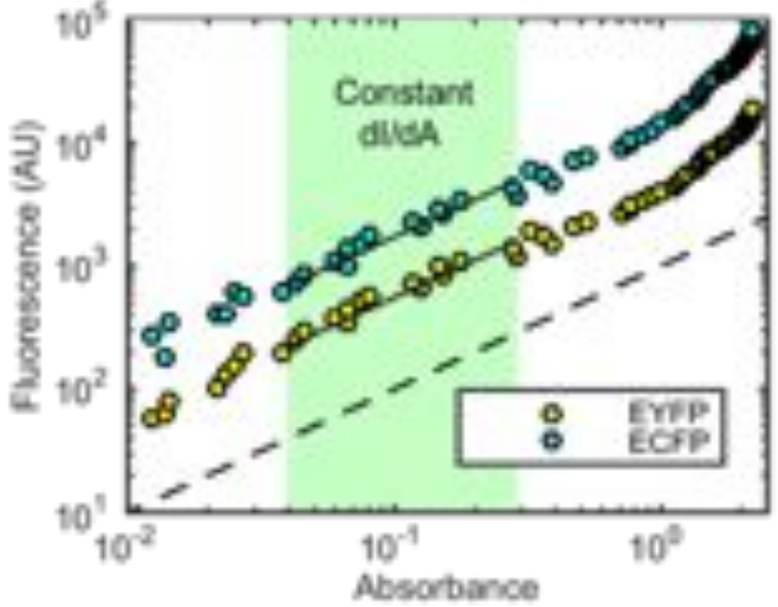
Molecular
(nm, seconds)

Cellular
(μm, minutes)

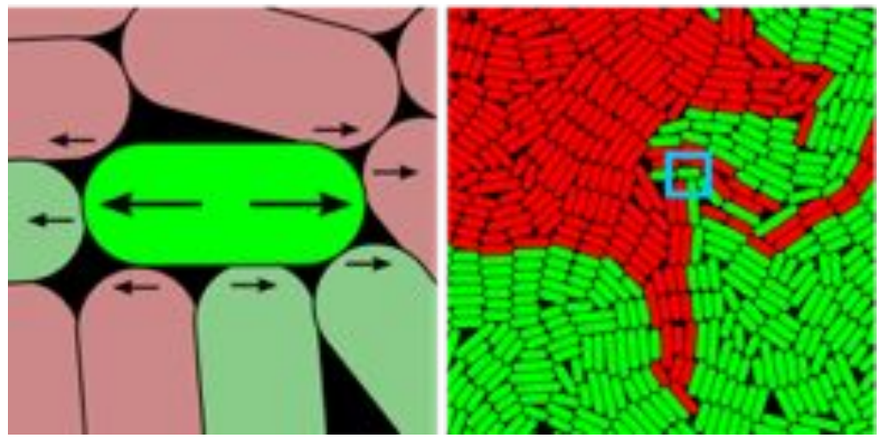
Population
(mm, hours)



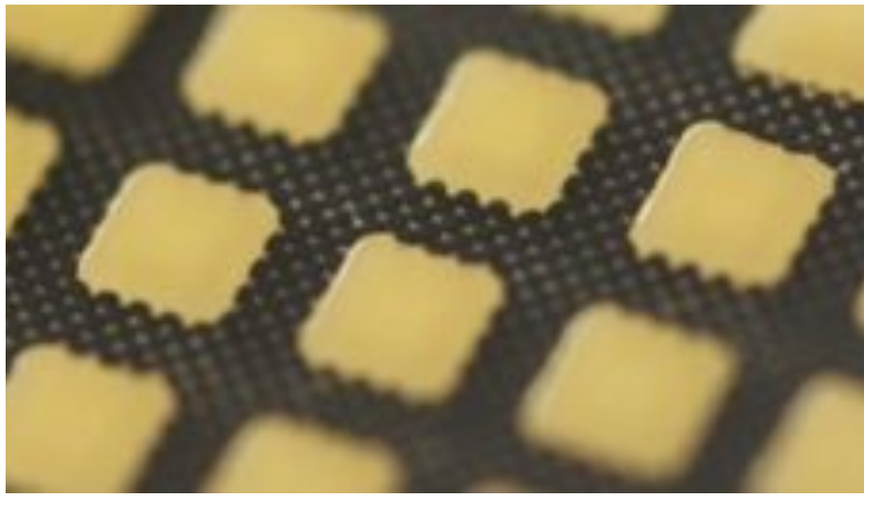
Rudge et al. ACS Synthetic Biology 5:89-98. (2016)



Rudge et al. ACS Synthetic Biology, 2:705–714, (2013)



Grant et al. Molecular Systems Biology 12:849-861, (2016)



GPU-accelerated physico-genetic models

Growth of marked daughters into 100,000 cell colony

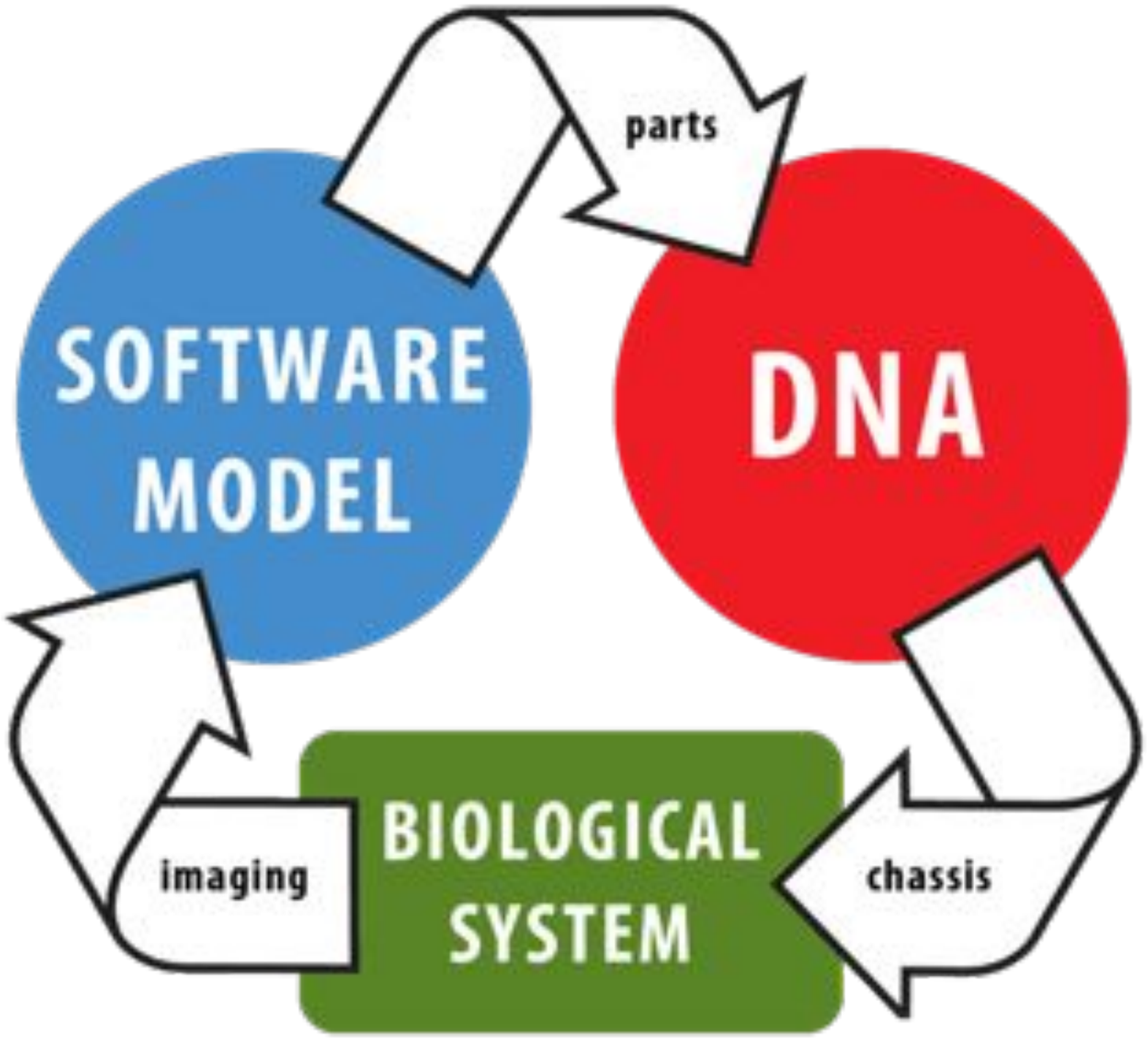
Tim Rudge & PJ Steiner

Design, build and test cycle for Synthetic Biology systems

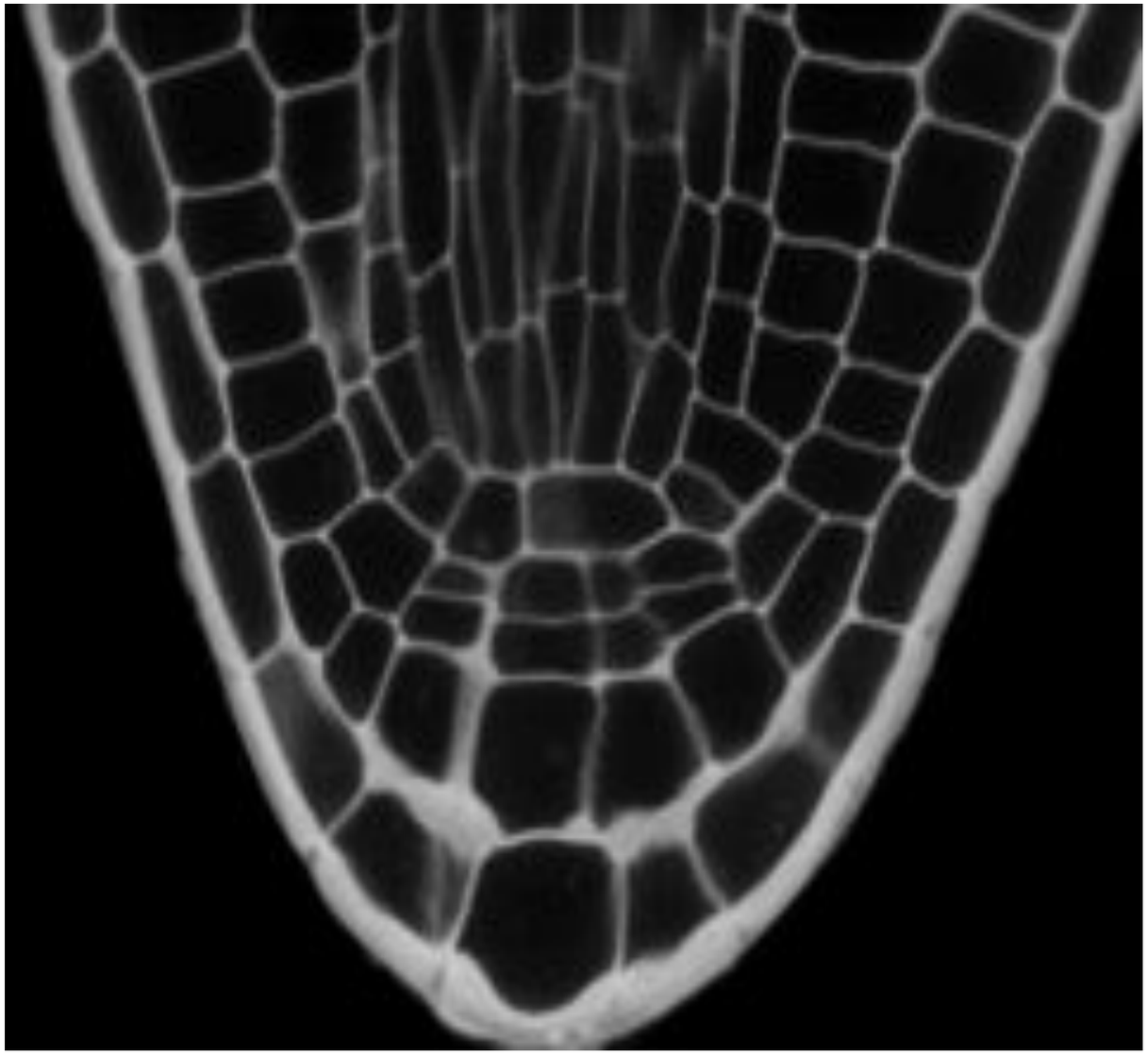
1. Specification and design of the system using computer models of the biological system

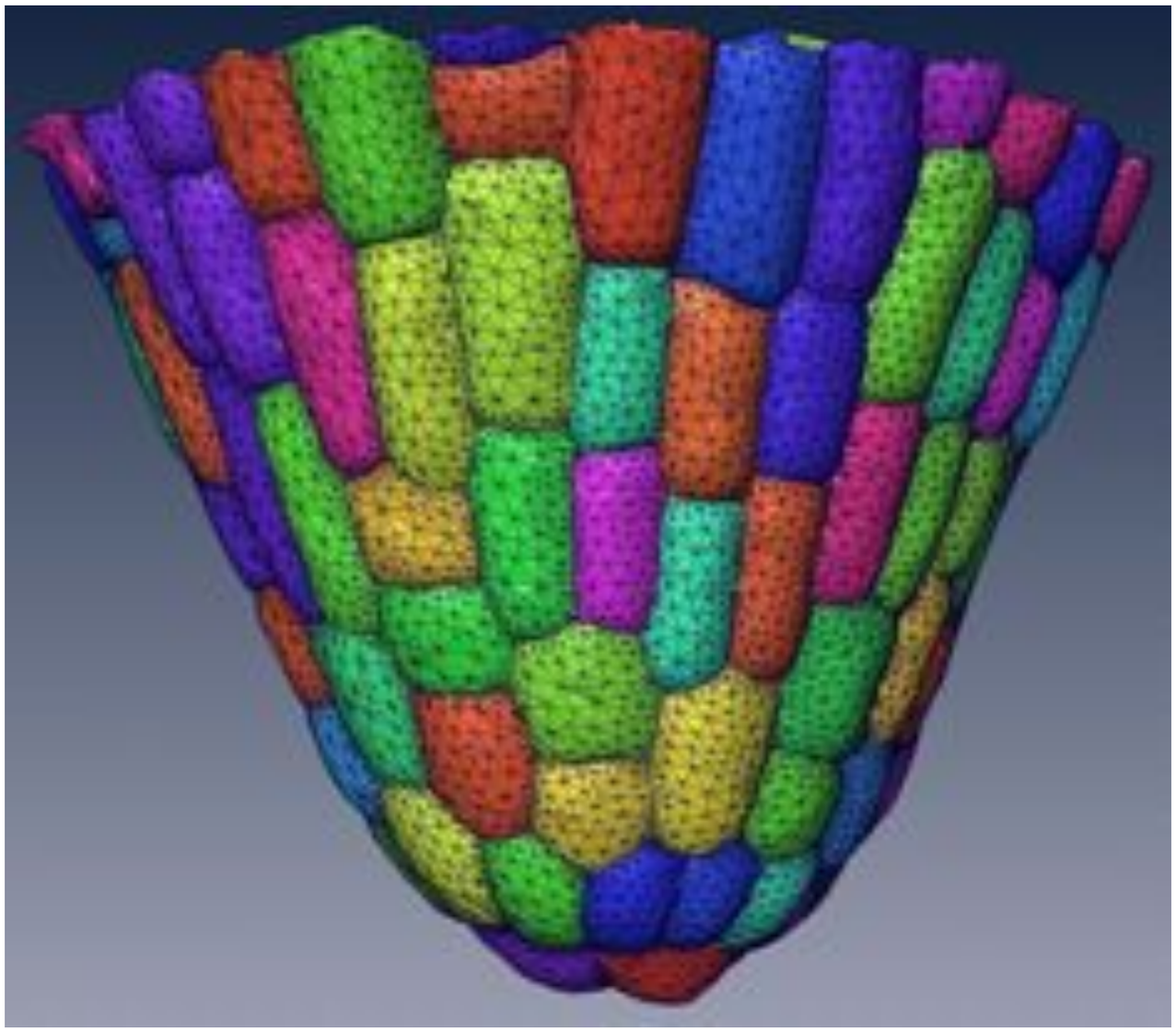
2. Construction of genetic circuits using standard DNA parts and high throughput assembly techniques

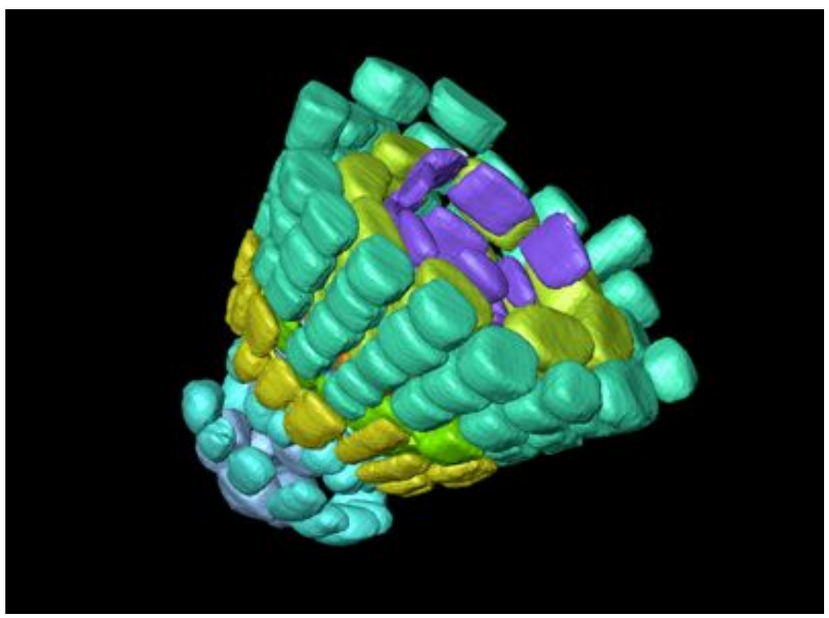
3. Transformation of chassis and visualisation of gene expression, cell states and phenotype

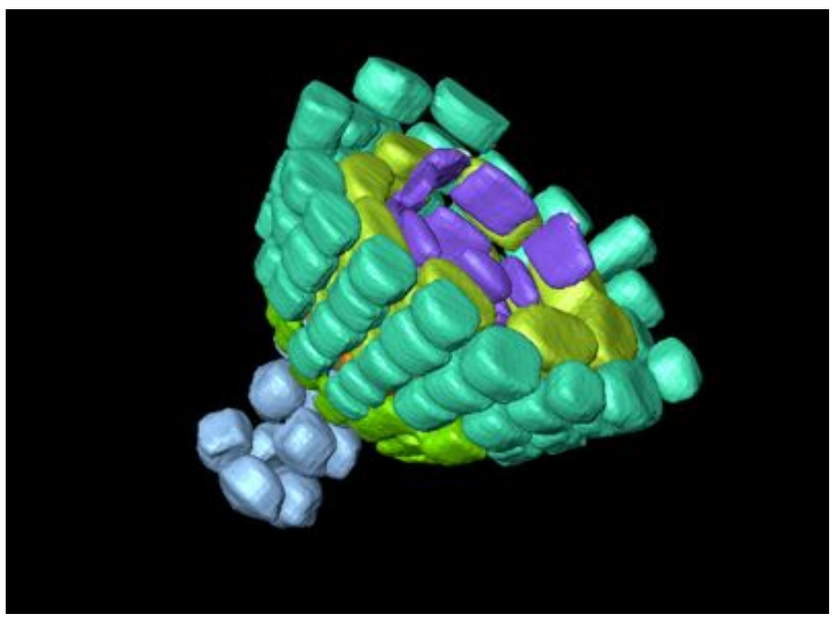


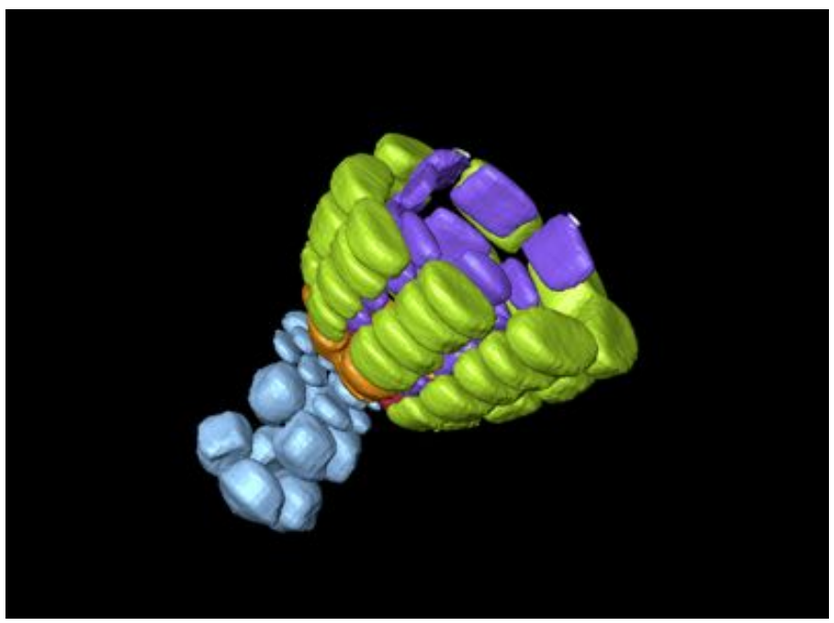
Quantitative analysis of plant cell geometry and gene expression











Ratiometric imaging of nuclear localised markers for standardised measurement of gene expression

Lionel Dupuy & Fernan Federici

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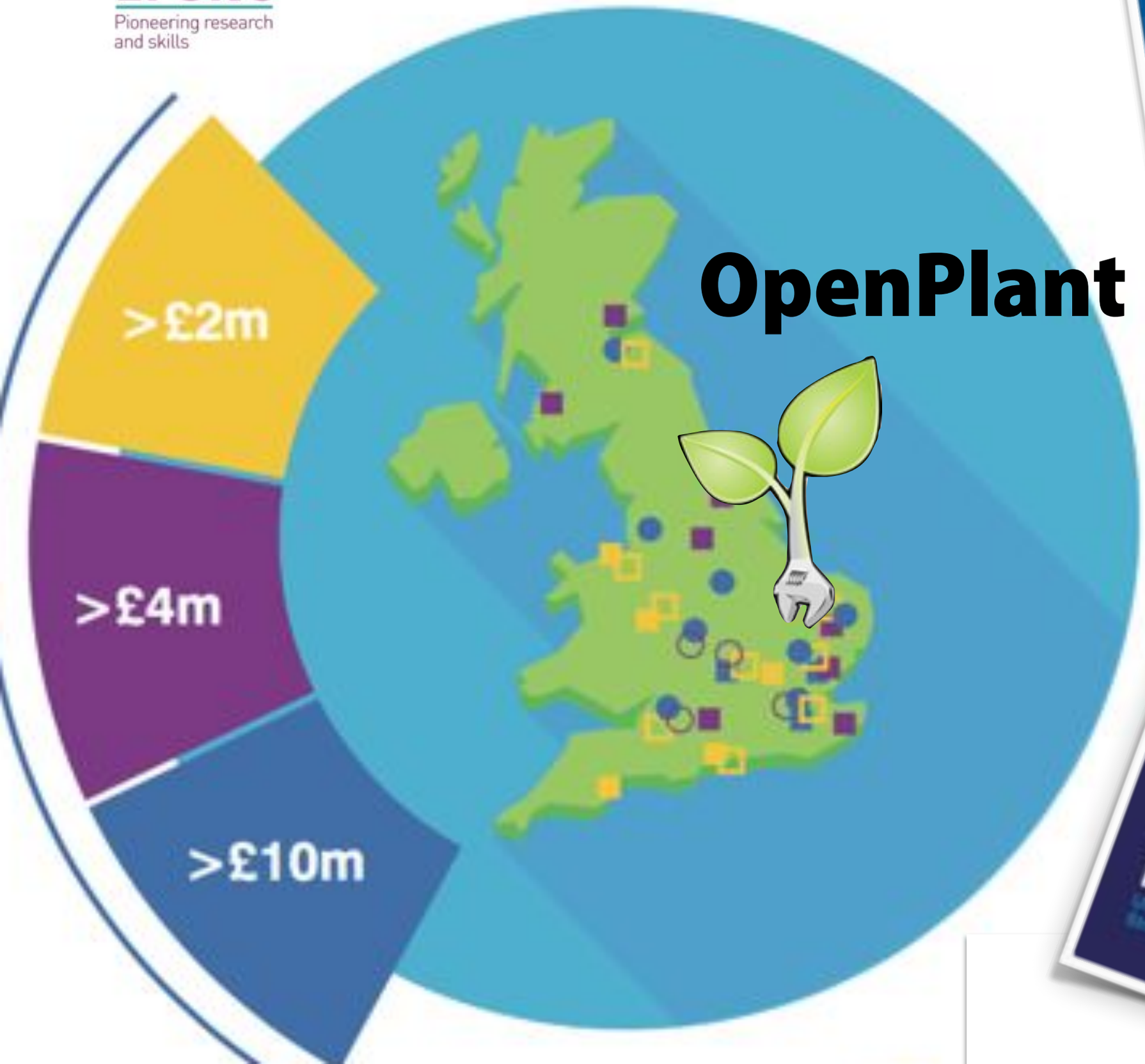
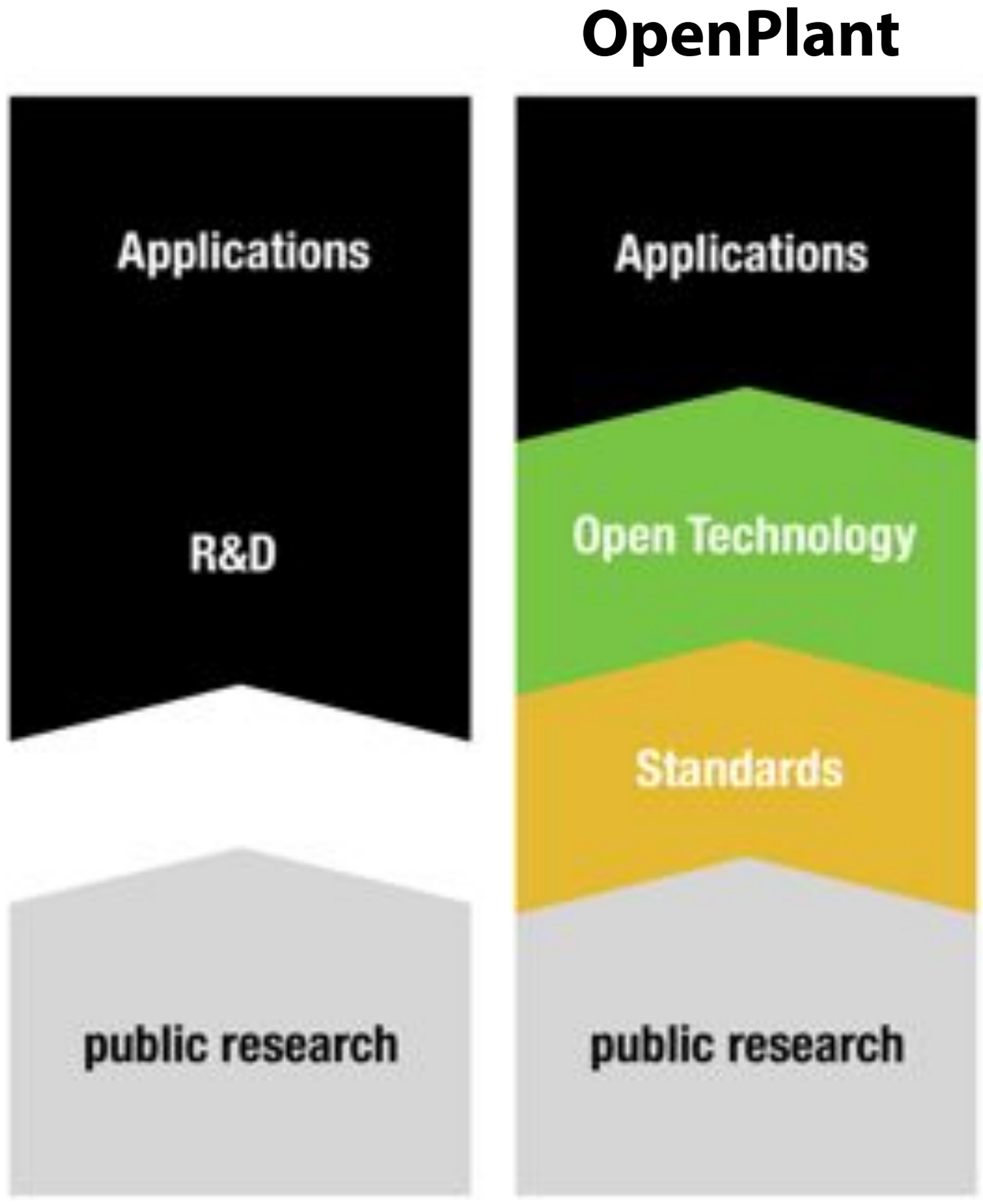
OpenPlant



Electronics	Biology
VLSI chips, hardware	commercial bioproducts
Linux, open hardware	model systems
connectors, protocols	DNA parts, assembly
academia	academia



Open standards and technologies for engineering plants

OpenPlant objectives

- **Standardise plant DNA components**
- **Open distribution of DNA parts**
- **BioRxiv based publication system**
- **Establish simple testbed for reprogramming plants (OS)**
- **Chloroplast genome engineering**
- **Development of interdisciplinary curricula and shared resources for project-based teaching and research**

OpenPlant & Synbio SRI Forums and Workshops

SCIENCE MAKERS

Cambridge BioMakespace

Promoting interdisciplinary exchange

Cambridge funding programme for mini-projects

SynBio Fund & OpenPlant Fund 2015 Projects (~$1M over 5 years)

Examples of interdisciplinary projects:

Open Pi-Image: A low cost-open source plant growth imaging and analysis platform

Open Labware for plant electrophysiology

Wireless, portable, low cost, open source hardware for monitoring plant electrophysiology

Whiskeroscope: rodent whisker inspired sensor for use in analysis of plant tissue structure.

Facilitating synthetic biology literature mining and searching for the plant community

Flexible, low cost, live cell imaging platform: Continued development of a flexible, low cost, live-imaging platform for long term monitoring of cell behaviour in vitro

Interactive web-based software for genetic circuit design.

The Green Mother Machine: a microfluidics device for cyanobacteria: Optimising a microfluidic chemostat for experiments using cyanobacteria, including growth and feeding channels.

Examples of international projects:

DocuBricks: documentation tool for open plant technologies

DIY Biolab: DIY Biolab plan to build and document open hardware for molecular biology.

Strengthening synthetic biology capacity in Kenya through bioinformatics training

Setting up an open synthetic biology lab in Abuja, Nigeria

Fluorescence and phase contrast functions in a low-cost, 3D-printed microscope and demonstrating its use in an incubator.

iGEM
Cambridge - JIC
OpenScope

http://2015.igem.org/Team:Cambridge-JIC

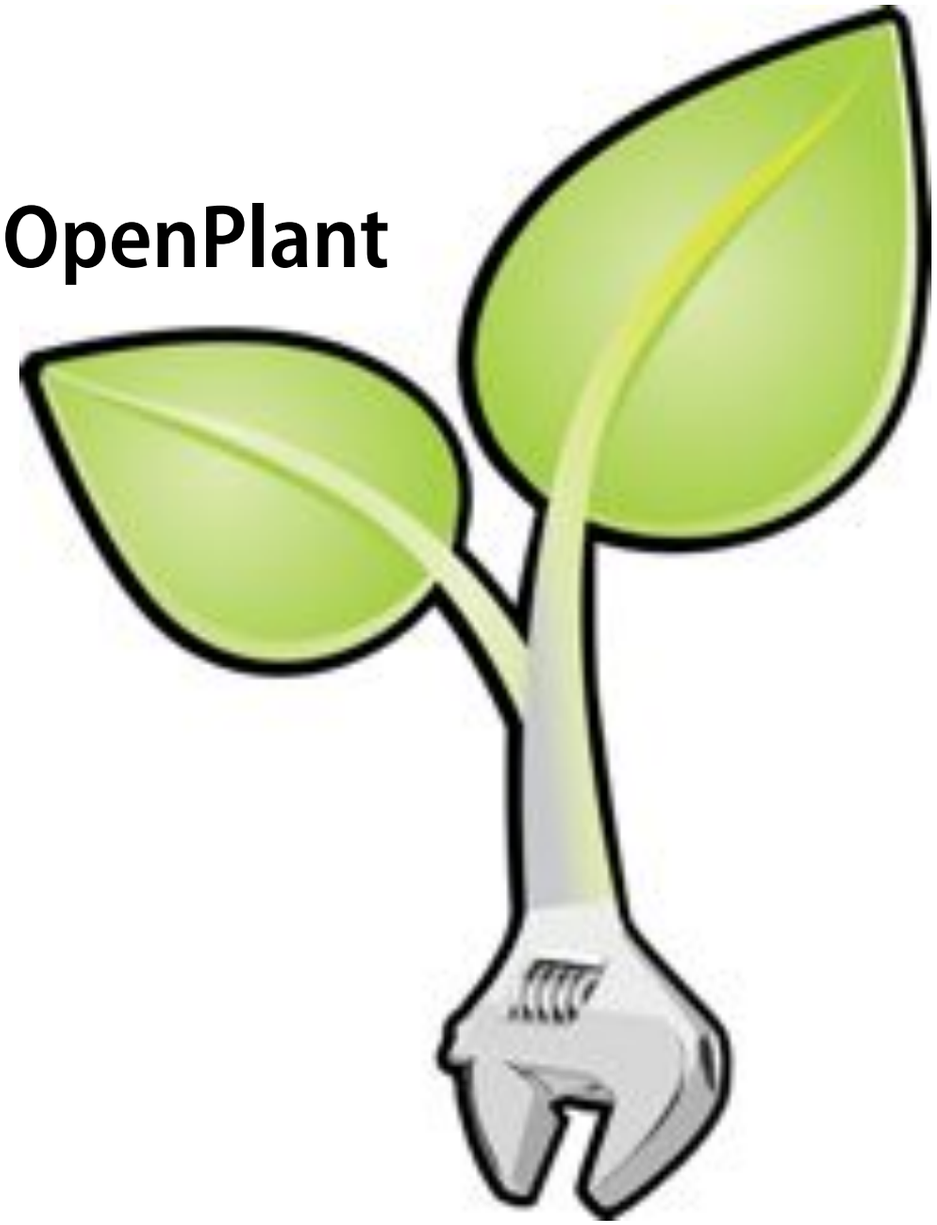
iGEM: International Genetically Engineered Machine competition

300 iGEM teams
25,000 iGEM alumni since 2003

TechnoX

Propagation of new plant standards and tools through iGEM

OpenPlant



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