Microbial engineering for renewable energy and sustainable manufacturing

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Microbial Engineering: Metabolic Engineering

- Biofuels
- Commodity chemicals
- Specialty chemicals
- Pharmaceuticals
- Food

*Nature 488, 320-328 (16 August 2012)*
Microbial Engineering: Protein Production

Nature 488, 320-328 (16 August 2012)

- Biofuels
- Commodity chemicals
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Advanced Biofuels: Branched-chain higher alcohols (BCHAs)

- Isobutanol (C4)
- 2-methyl-1-butanol (C5)
- 3-methyl-1-butanol (C5)
Commodity Chemicals: Diols

1,3-Propanediol

1,4-Butanediol

Polyurethanes
- Unsaturated polyester resins
- Solar and Geothermal systems
- Low-temperature, food-safe fluids
- Engine coolants

DuPont Tate & Lyle BioProducts

genomatica
Bioplastics: Polyhydroxyalkanoates (PHAs)
Biodegradable fibers: Polyhydroxyalkanoates (PHAs)
Animal substitutes: Food and materials
Flavors

- Diacetyl
- Isovaleric acid
- Acetoin
- Methional
- Heme
- Hemoglobin
Food dyes

Astaxanthin
Fragrances

Limonene
Nootkatone
Linalool
Lilac alcohol
Pharmaceuticals

**Artemisinin**
- **Chemical structure**
- **Artemisia annua**
- **Tu Youyou**
- **2015**

**Taxol**
- 2-4, 100 year-old trees to treat 1 patient
- **$13,000 - $20,000 / week**

**Pacific Yew**
- **Image**
- **2-4, 100 year-old trees**
Spatial and temporal control of metabolic pathways to boost production

Saccharomyces cerevisiae

Escherichia coli

Yarrowia lipolytica

Pichia pastoris
Organelle compartmentalization: Mitochondria

Image: flickr.com/col_and_tasha; National Botanic Garden of Wales

Mitochondrial morphology and dynamics

Fermentation

Respiration
Dynamic control: Optogenetics


Fed-batch bioreactor operated with periodic light pulses

Isobutanol titer: 8.49 ± 0.31 g/L
2-methyl-1-butanol titer: 2.38 ± 0.06 g/L
Total fusel alcohol titer: 10.87 ± 0.06 g/L
Isobutanol yield: 53.5 ± 8.4 mg/g
% Theoretical Isobutanol yield: 13%

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