Synthetic Genomics
Options for Governance

Michele S. Garfinkel
J. Craig Venter Institute
Synthetic genomics at JCVI

- ΦX174 synthesis
External Events Influence How a Technology is Perceived

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100,000
10,000
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Size of project (bp)

Year of publication

't75 '80 '85 '90 '95 '00 '05 '10

Mycoplasma genitalium
JCVI 1.0

PKS gene cluster

phiX

poliovirus

gene + plasmid

tRNA

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September 11, 2001

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J. Craig Venter INSTITUTE
Governance Concerns Related to Synthetic Genomics

- Along with the promise of benefits, *all* new technologies raise societal concerns

- Five key societal concerns:
  - Bioterrorism
  - Laboratory Safety
  - Harm to the Environment
  - Distribution of Benefits
  - Ethical and Religious Concerns
Bioterrorism

• Societal concerns
  o New way to obtain pathogens
  o Construction of a pathogen with increased resistance to known treatments or increased virulence

• What is different about synthetic genomics?
  o Can no longer limit access by physical means alone
  o Most pathogens easier to obtain by other means
    – Except a few viruses: 1918 influenza, Smallpox, Ebola
Laboratory Safety

- Societal concerns
  - Concern is for risks to users from specific microbes
    - No concern for harm to users from synthetic DNA itself
- What is different about synthetic genomics?
  - Speed and scale
  - Researchers new to the field
SYNTHETIC GENOMICS | Options for Governance

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October 2007
<table>
<thead>
<tr>
<th>Does the Option:</th>
<th>Enhance Biosecurity</th>
<th>Foster Laboratory Safety</th>
<th>Protect the Environment</th>
<th>Other Considerations:</th>
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</table>
A synthetic chromosome

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**Synthesis of M. genitalium genome**

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<tr>
<th>Watermarks</th>
<th>2006 Transposons</th>
<th>1999 Transposons</th>
<th>Synthetic DNA Cassettes</th>
<th>Protein Coding Genes</th>
<th>Structural RNAs</th>
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TIME

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10 MICRONS
Synthetic genomics at JCVI

- Enzymatic assembly of multi-kilobase molecules
Synthetic genomics at JCVI

- One-step assembly of *M. genitalium* genome
Schematic overview and timeline for the assembly of overlapping ssDNA oligonucleotides (orange lines with blue circles) into a linear dsDNA yeast/E. coli shuttle vector (pRS313; grey) within the nucleus of a yeast cell.
Twenty base-pair overlaps are sufficient for oligonucleotide assembly in yeast

Societal Concerns Related to Synthetic Genomics

- Five key societal concerns:
  - Bioterrorism
  - Laboratory Safety
  - Harm to the Environment
  - Distribution of Benefits
  - Ethical and Religious Concerns
Harm to the Environment

• Societal concerns
  o No concern for harm from synthetic DNA itself
  o Only concern is whether specific engineered organisms pose risks to the environment
  o Part of larger societal debate about rDNA since the mid-1970s (starting with Asilomar)

• What is different about synthetic genomics?
  o Speed, scale, power of the technology
Distribution of Benefits

- Societal concerns
  - Intellectual property concerns
    - Patents, open source
  - “Concentration” within a small number of firms
- What is different about synthetic genomics?
  - Maybe little; raised for every emerging technology
  - However, the synthetic biology community itself is divided on this issue
Ethical and Religious Concerns

• Societal concerns
  o Hubris (“playing God”)
  o Concerns about changing the relationship of humans to nature

• What is different about synthetic genomics?
  o Construction of a free-living organism from chemicals adds a new concern to the list
<table>
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<td>• Citizens</td>
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<td>• Scientists</td>
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<tr>
<td>• Policymakers</td>
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<tr>
<td>• Governments</td>
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<td>• Do-it-yourself community</td>
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And their representative groups
Regulation and governance of synthetic genomics

- Changes to NIH guidelines?
- Changes to Coordinated Framework?
- Changes to TSCA?
- Changes in patent review (domestic and international)?
Where we are today...

- The technology is improving and the user base is expanding
- Applications are beginning to appear and many new ones are being developed
- Societal impacts are being scrutinized
- Governance options are being seriously considered...
  - By the research community itself, the developing industry, and by governments
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