CYBERSECURITY IN BIOMANUFACTURING

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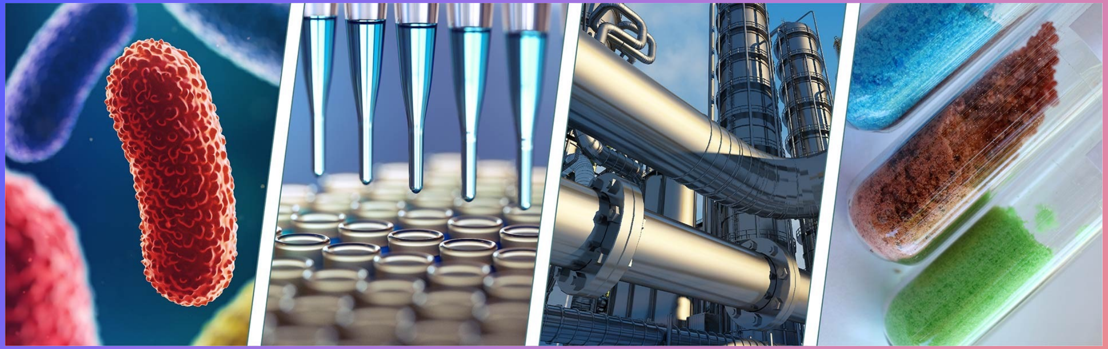


Biomanufacturing

- Biological systems (cells, tissues) → valuable products
- 2020: ~$19B market
  - $85B market by 2031 (annual growth rate of 15%)
- Addresses many major future issues
  - Medicine/health
  - Water/food security, climate change
  - Sustainable energy

Cybersecurity implications in biotech

- Many stakeholders: healthcare, government, industry
- Interruptions to global production, pandemic response
- Sensitive medical data
  - Data breaches in healthcare industry: up 10% each year 2010-2019
- Recent sabotage, IP theft, extortion attempts on systems in biotech industry

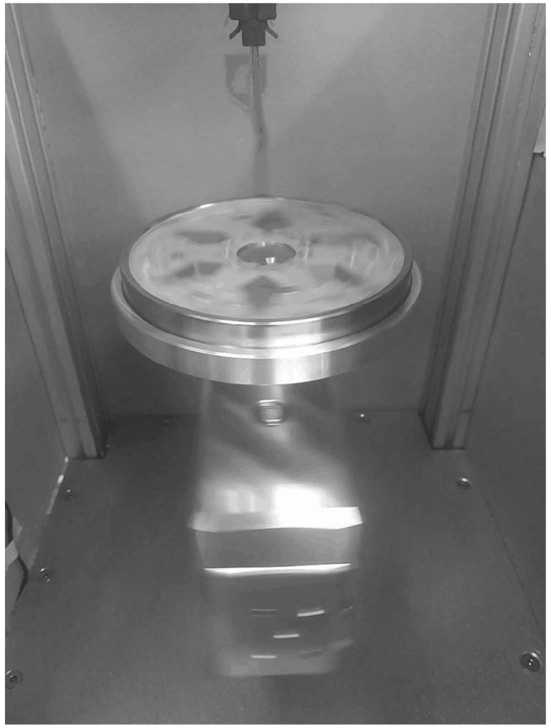
Example: Merck & Co, 2017

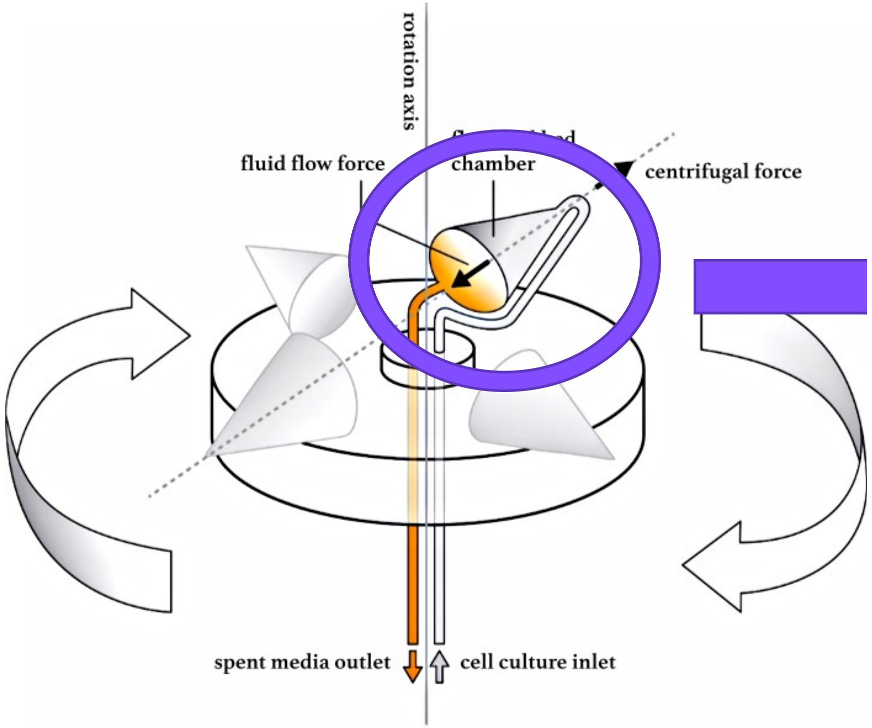
- Modified ransomware worm: encrypted data on computer systems
  - Affected the manufacturing facility
  - Vaccine shortages, Merck had to borrow from CDC
- Total cost of attack: ~$1 billion
- US/UK attributed attack to Russia
- No evidence that Merck was specifically targeted

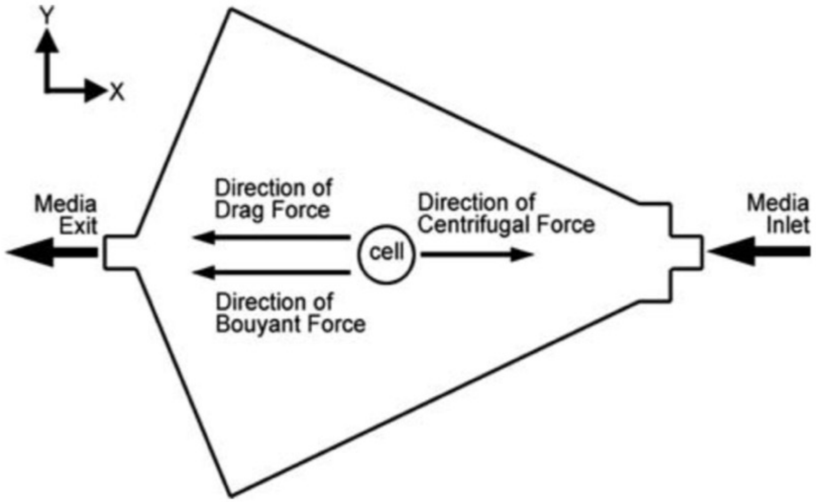
Next Gen Biomanufacturing

- Cyberbiosecurity in future: More attacks, more specific targets
- Old industry standard: large-scale equipment, bioreactors
  - Vulnerable, interruption of production = major risk
- Shift towards smaller, more flexible, systems for more patient specific therapy
  - Need to develop new approaches to cybersecurity in biotech
- Process control, digital automation
- Network-connected systems: vital
  - Remote access, automation, data handling etc.
  - Important but introduces vulnerability
  - Change design approach to account for possible cyberattacks

Centrifugal Bioreactor (CBR)







- Application: growth of T cells for cancer immunotherapy
    - More efficient than existing industry standard

Mathematical Modeling of CBR

$$\frac{\partial C_{cell}}{\partial t} = \mu_{max} \cdot \left(1 - \frac{C_L}{C_{L\_max}}\right)^n \cdot \left(1 - \frac{C_A}{C_{A\_max}}\right)^m \cdot C_{Cell}$$

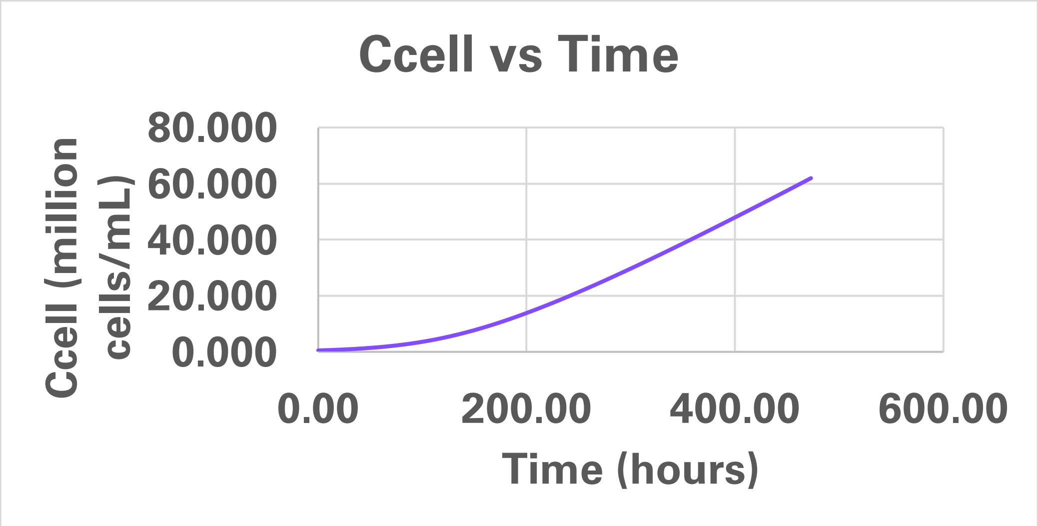
$$\frac{\partial C_G}{\partial t} = D(C_{G0} - C_G) - Y_{GC} \cdot \left(\frac{\partial C_{Cell}}{\partial t}\right)$$

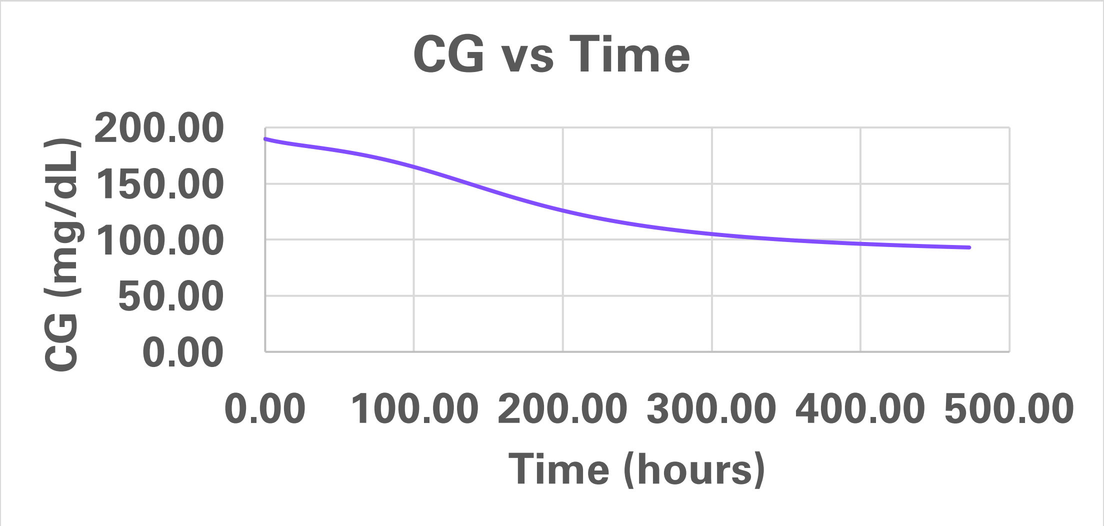
$$\frac{\partial C_A}{\partial t} = D(C_{A0} - C_A) + Y_{AC} \cdot \left(\frac{\partial C_{Cell}}{\partial t}\right)$$

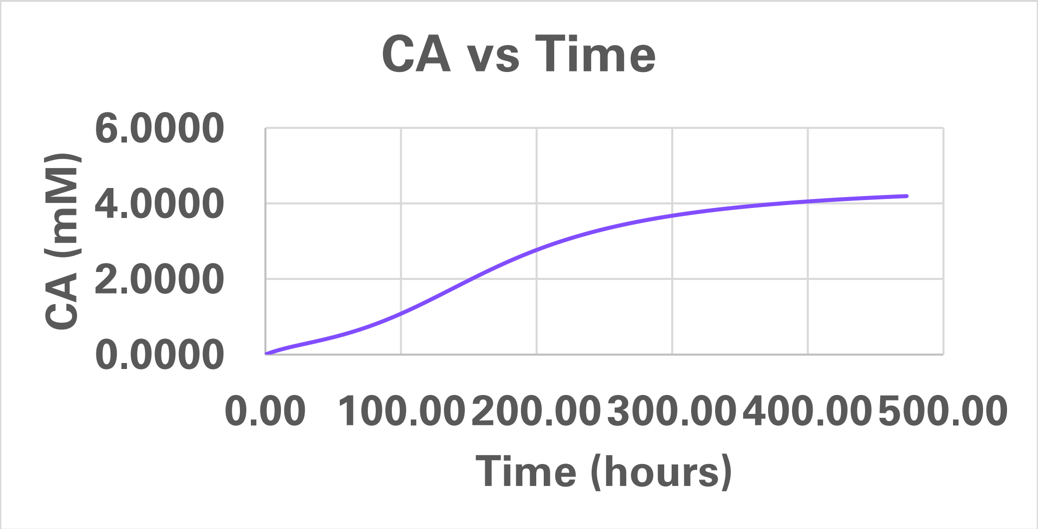
$$\frac{\partial C_L}{\partial t} = D(C_{L0} - C_L) + Y_{LC} \cdot \left(\frac{\partial C_{Cell}}{\partial t}\right)$$

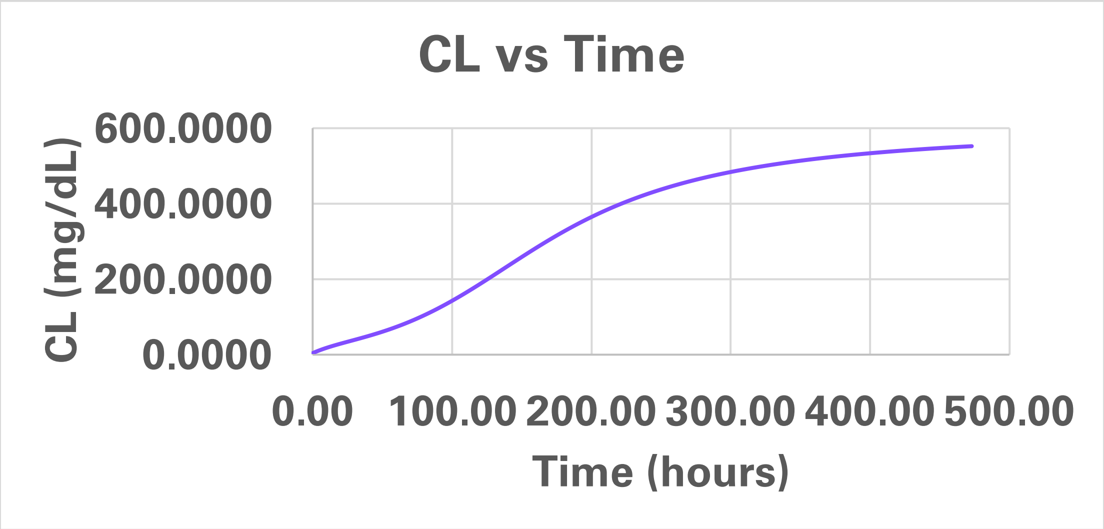
- Ccell = cell density
- Glucose (G)
- Ammonium (A)
- Lactate (L)
- Can use Runge-Kutta method to solve

Model Results









Feedback Control

- Next steps: online control system
- Monitor levels of G, L, A
  - Modify parameters in real-time in response to metabolite levels
- Network operations: control system remotely and facilitate transfer of data
  - Introduces risk of cyberattack
- Model developed to simulate cyberattacks – Dr. Gozen

Questions?

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Cougar Cage

- Sources:

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