

# Macroscopic Laws of Biology

Chris Kempes



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  - Laws of chemistry
  - General processes of natural selection
  - Laws of physics
  - Laws of life?

# Laws

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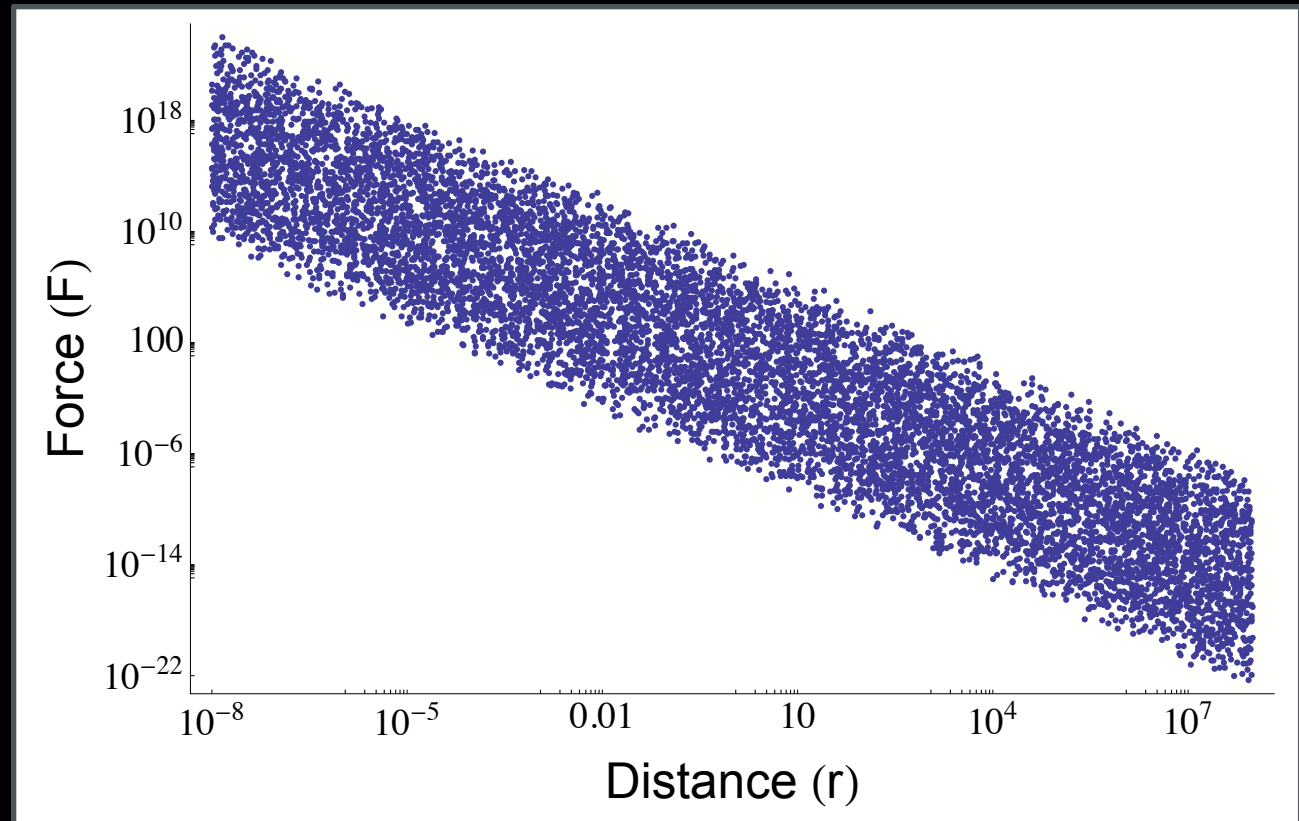
- Gravitation

$$F = \frac{Gm_1m_2}{r^2}$$

# Laws

- Gravitation

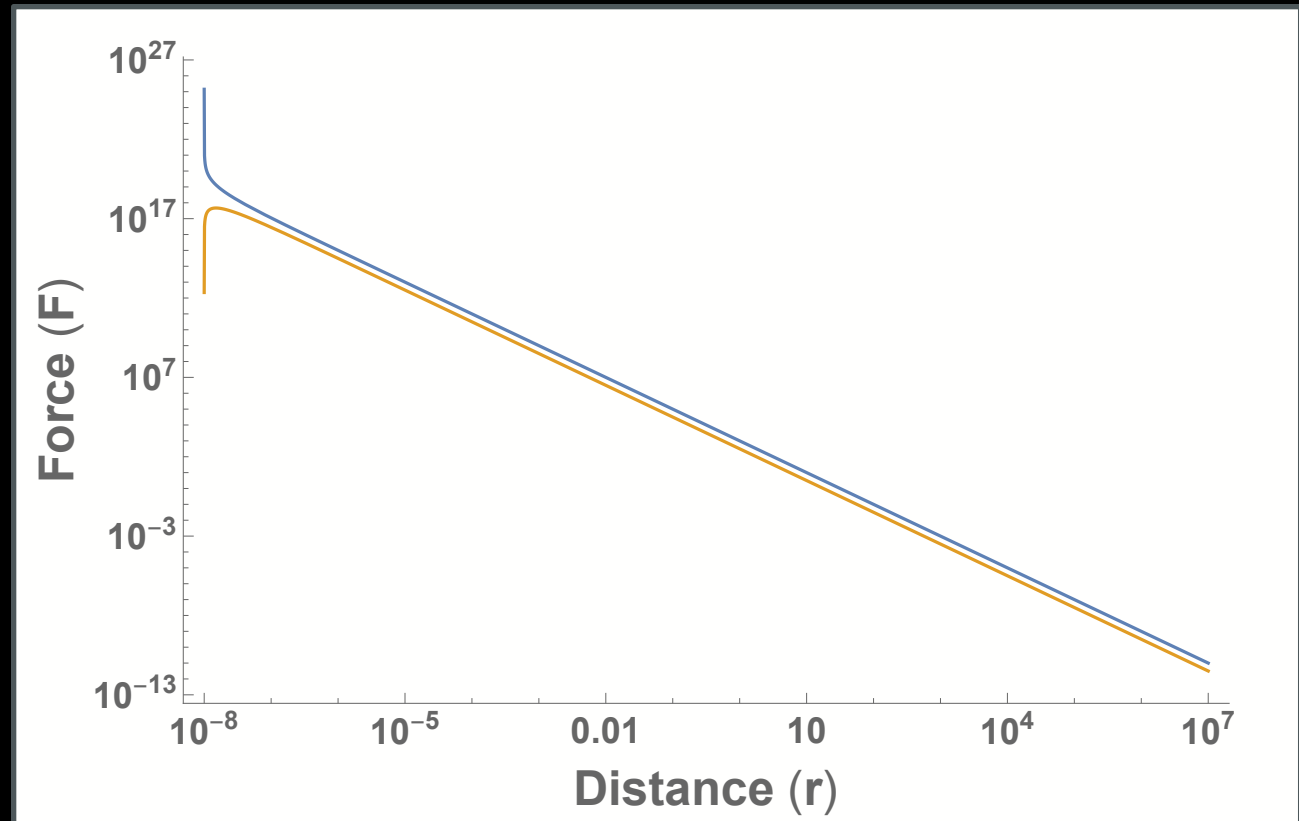
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# Laws

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# Laws in Biology?

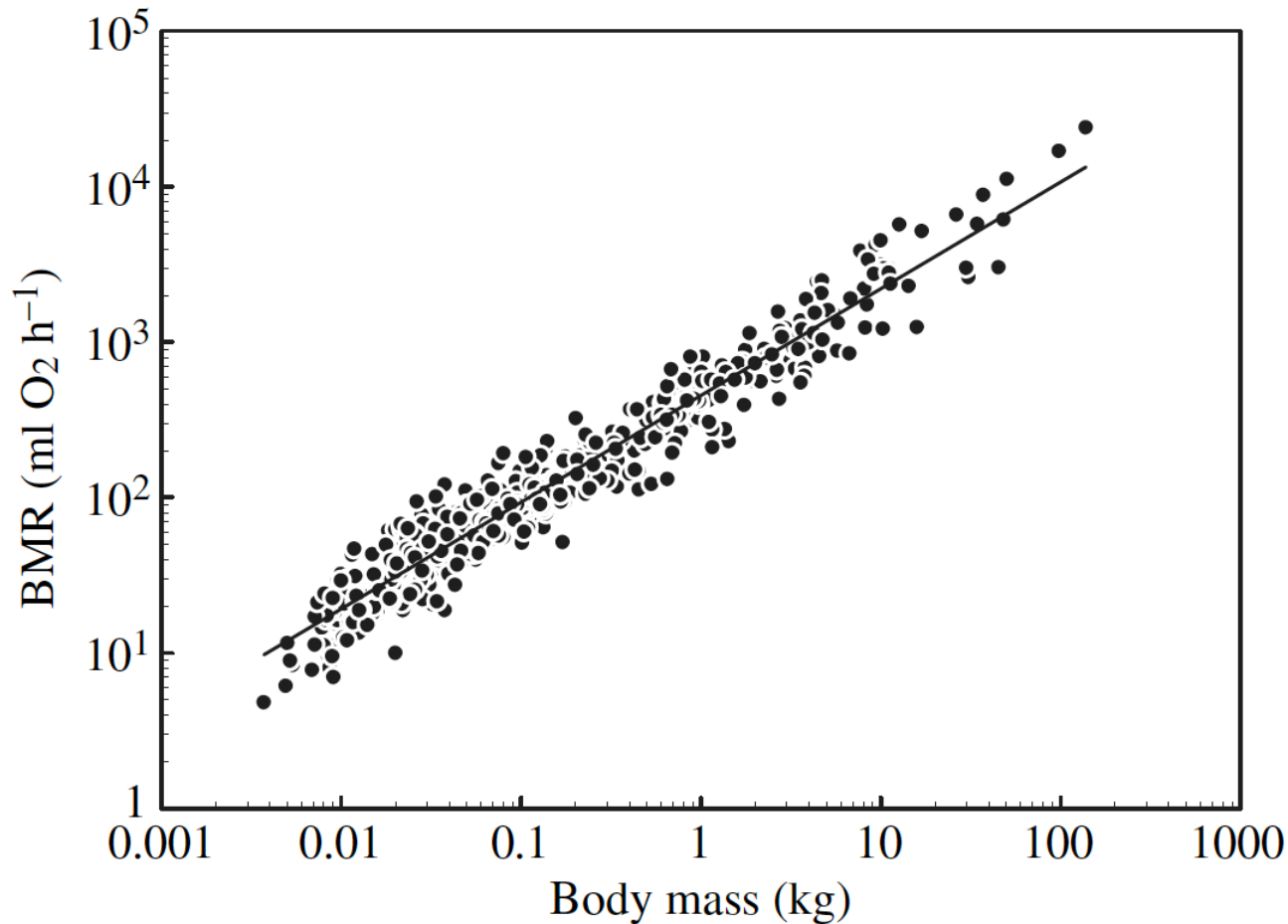
- **What is a law?**
- **What is a theory?**
- **What is a hypothesis?**
- **What is a model?**
- **What is a prediction?**
- **What is a principle?**
- **What is a rule?**
- **What is a guideline?**
- **What is a convention?**
- **What is a custom?**
- **What is a tradition?**
- **What is a habit?**
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# Laws in Biology?

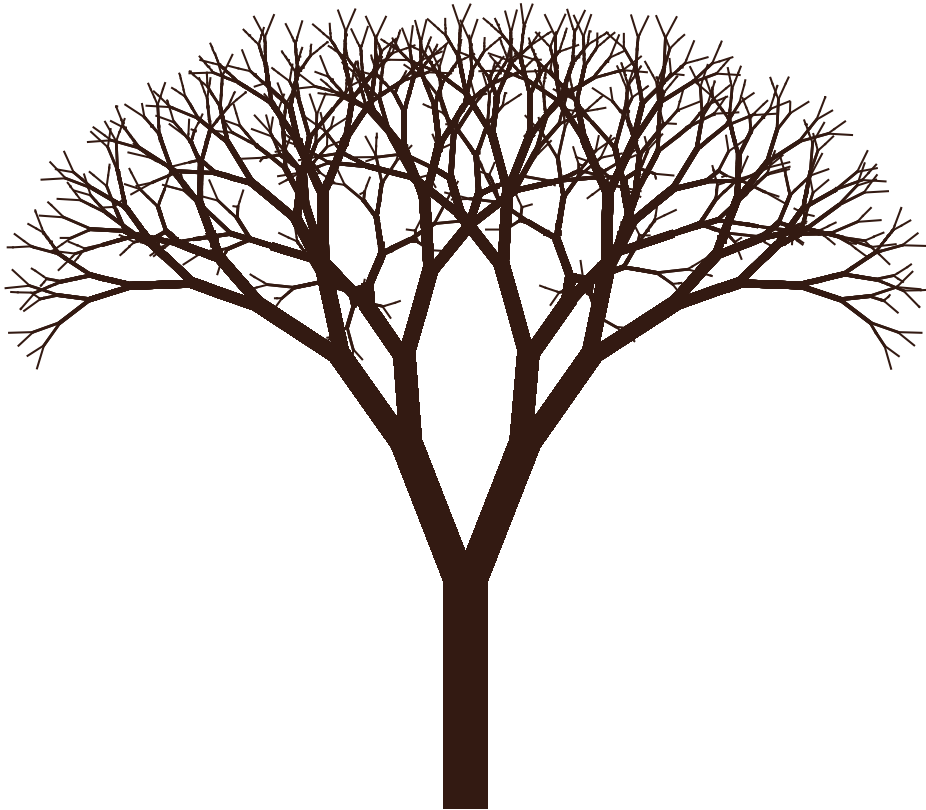
- Organisms evolve within the constraints of chemistry and physics.
- In certain contexts organisms can optimize physiology with respect to physical constants.

# An advanced example



White and Seymour, The Journal of  
Experimental Biology, 2005

# An advanced example



West, Brown, and Enquist, Science 1997  
Kempes et al. PLoS One, 2011

# Fundamental Constraints

• **Computational complexity**

• **Scalability**

• **Interoperability**

• **Security**

• **Performance**

• **Reliability**

• **Flexibility**

• **Cost**

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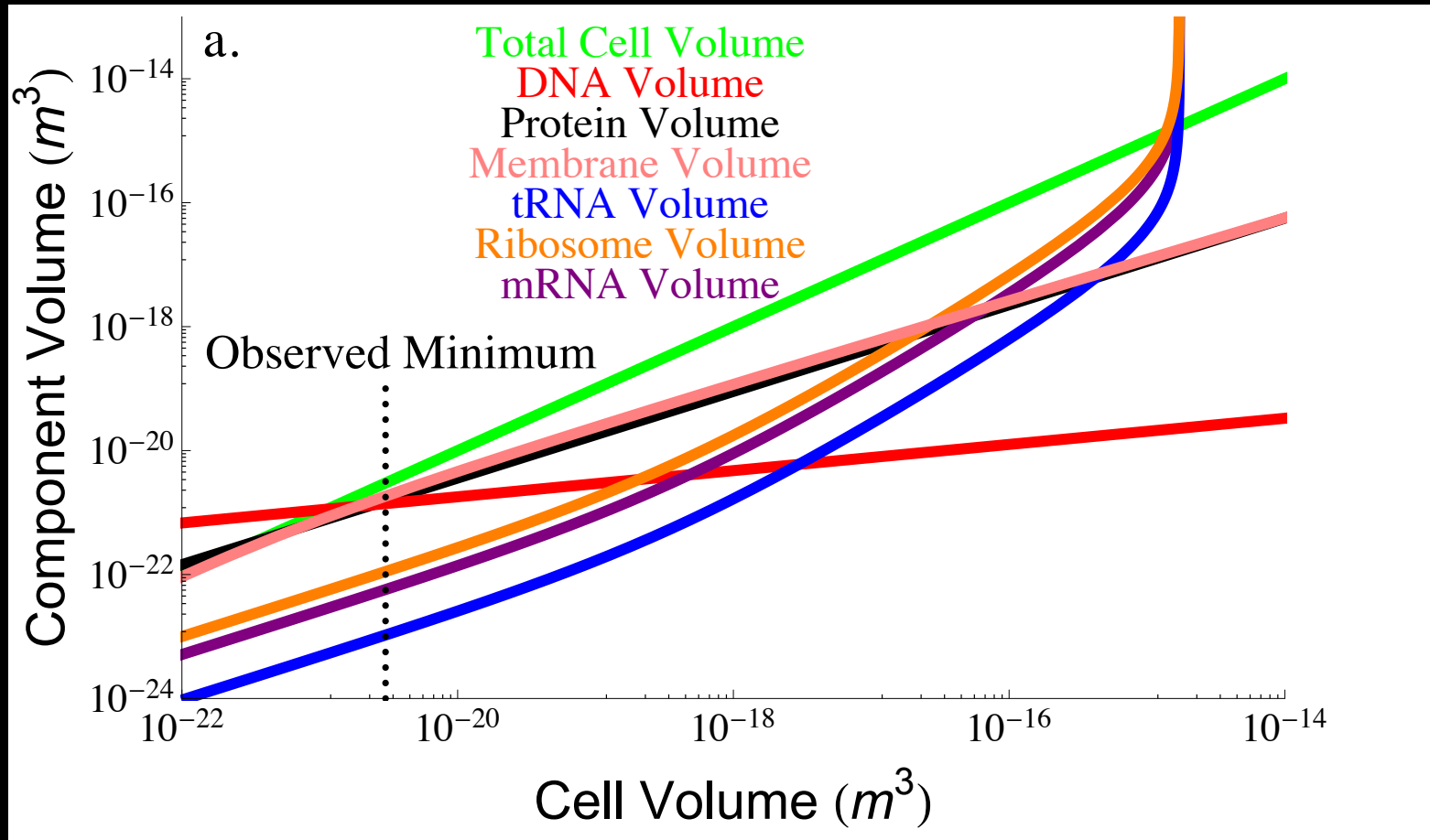
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$$U = 4\pi r_c^2 J(r_c) = 4\pi DC_{\infty} r_c$$

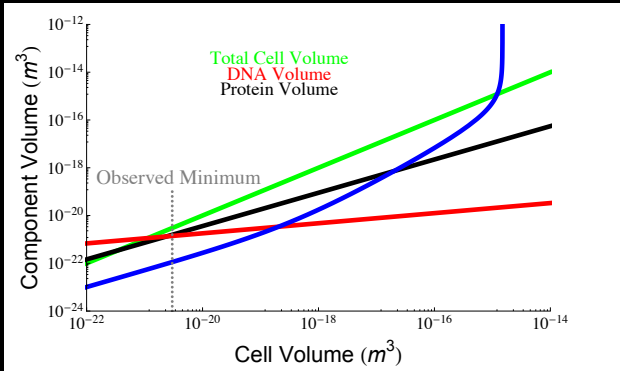
# Bacterial Physiology



Kempes, Wang, Amend, Doyle, Hoehler.,  
*ISME Journal*, 2016



# Generalized Physiology



all physiological possibilities