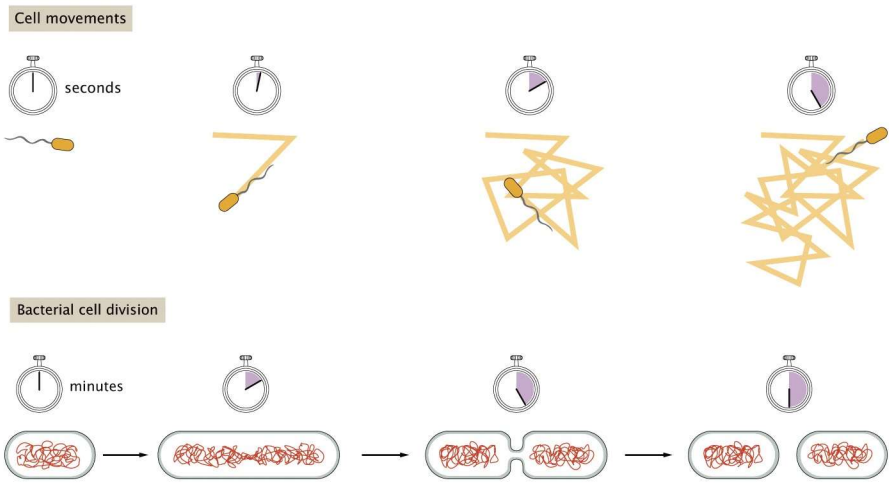
Quantitative principles in biological systems

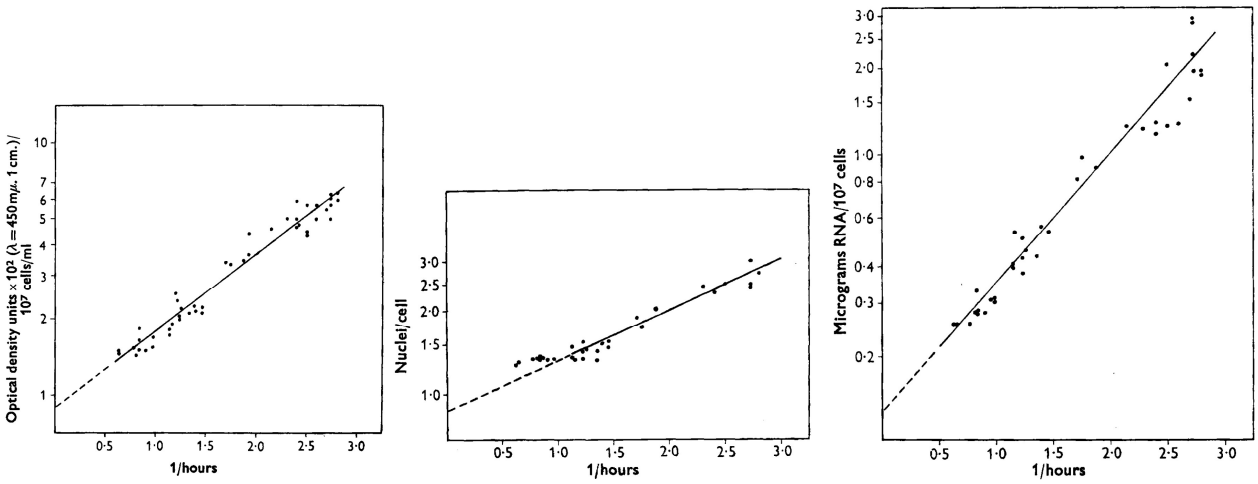
4. Bacterial growth and optimization

Spring 2026

Cell growth will be our model system for emergent functions.

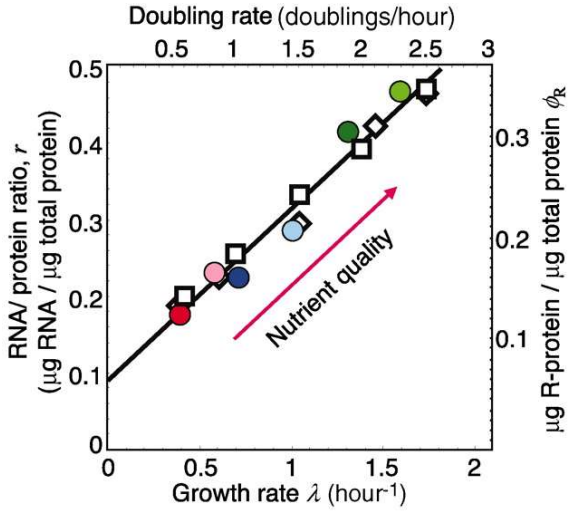


Growth laws



Schaechter et al. *J Gen Microbiol* (1958)

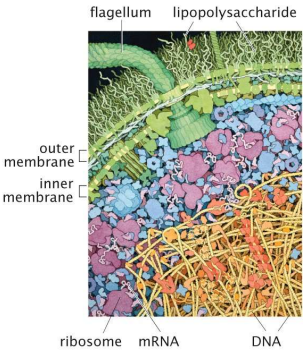
Ribosome concentration is proportional to growth rate.

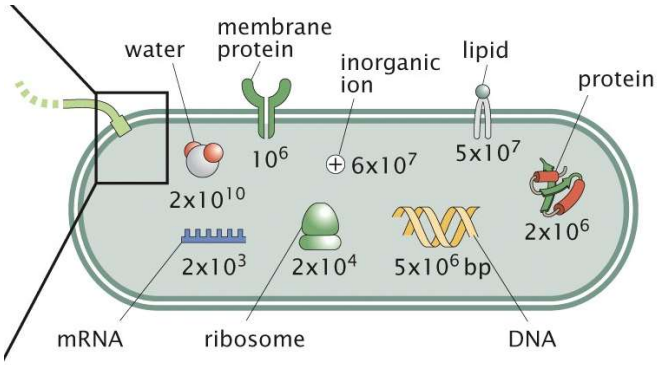


- Cell state is plastic.
- There are simple quantitative laws for biological systems.

Scott et al. *Science* (2010)

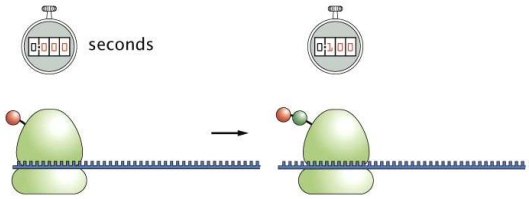
Inside an *E. coli* cell



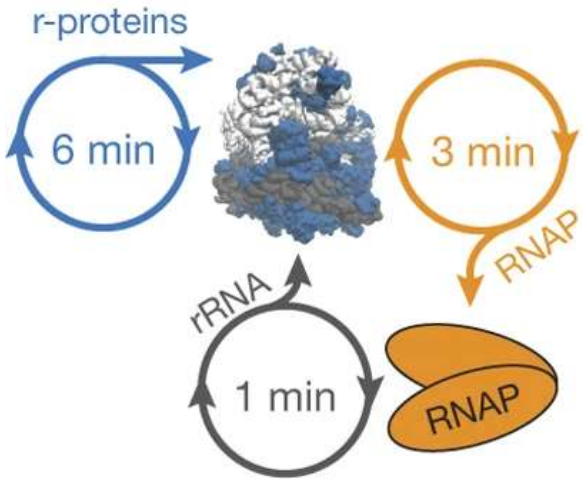


Protein synthesis

~20 amino acids per s

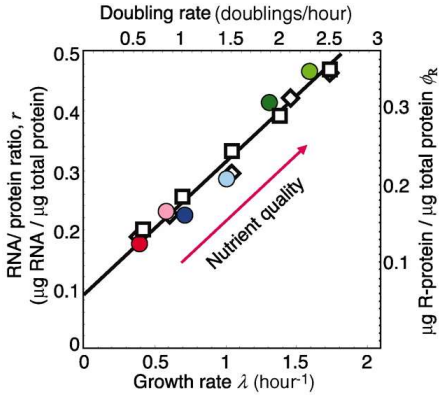


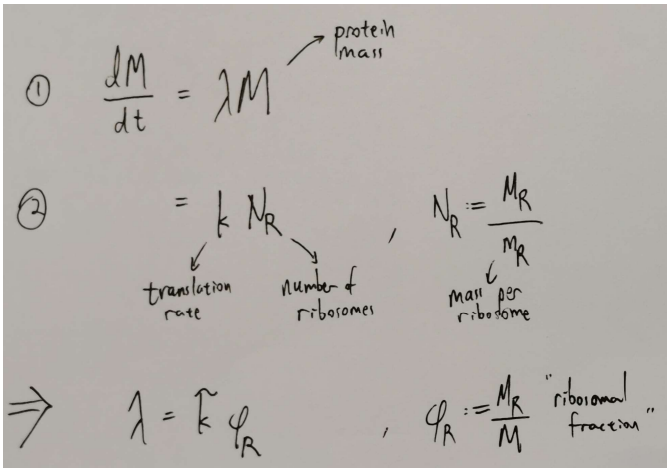
A costly autocatalytic cycle



Reuveni et al. *Nature* (2017)

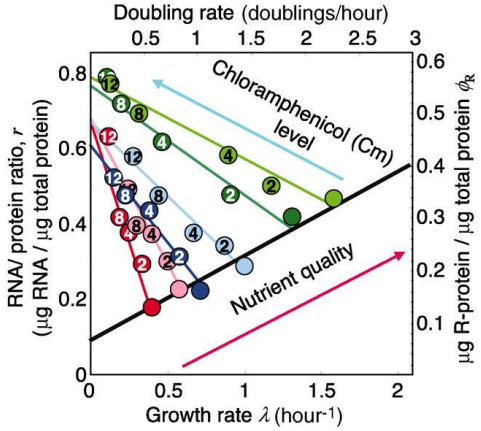
Ribosome fraction is proportional to growth rate…

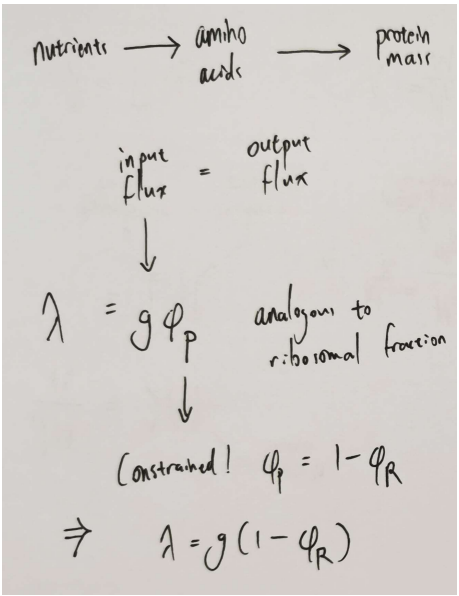




Scott et al. *Science* (2010)

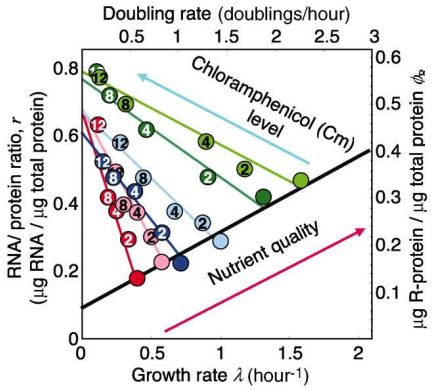
Ribosome fraction is proportional to growth rate when nutrient quality is varied.



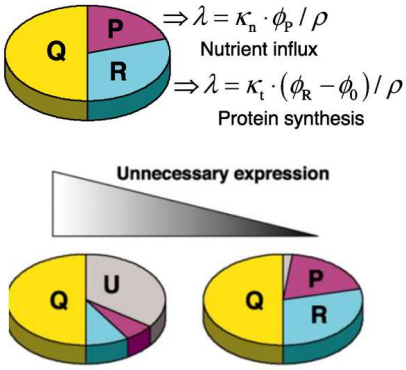


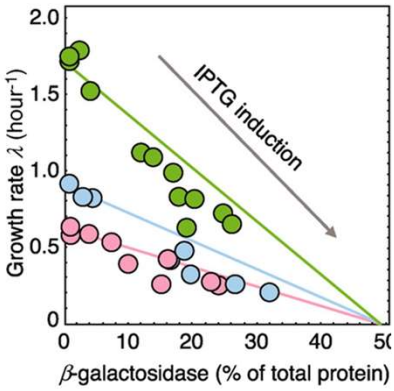
Scott et al. *Science* (2010)

Growth laws make quantitative, parameter-free predictions.



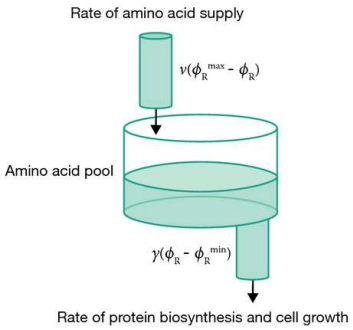
$$\phi_R + \phi_P = 1 - \phi_Q \equiv \phi_R^{max}$$

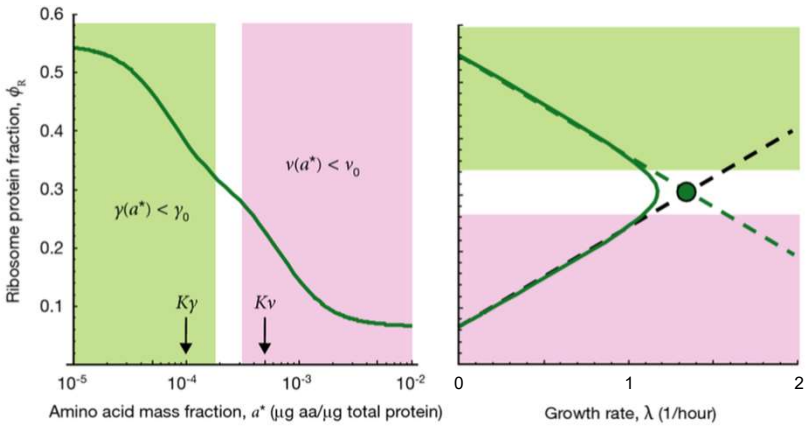




Scott et al. *Science* (2010)

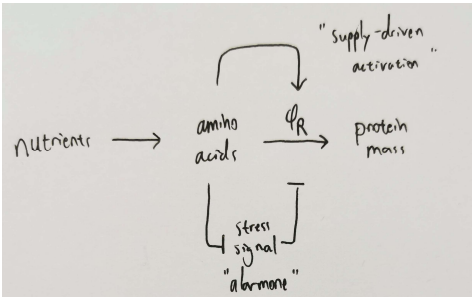
Ribosome fraction is free to vary under flux balance and determines growth rate.

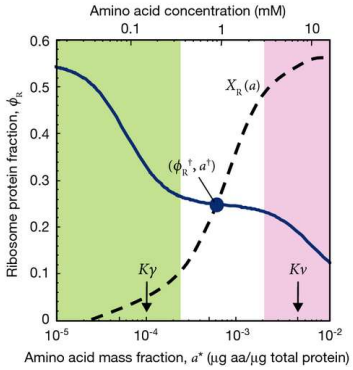


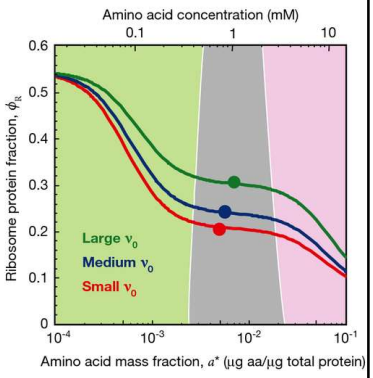


Scott et al. *Mol Syst Biol* (2014)

How is ribosomal fraction set?

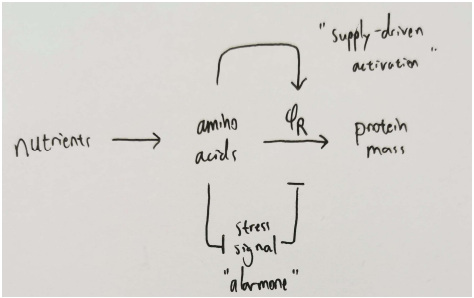


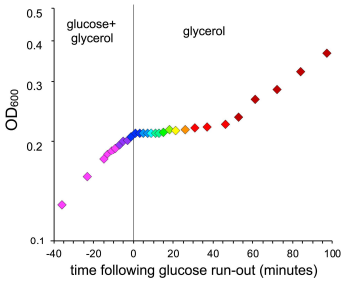


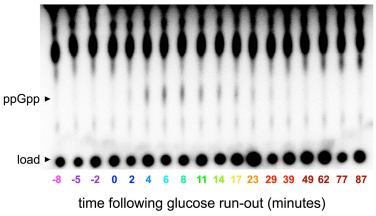


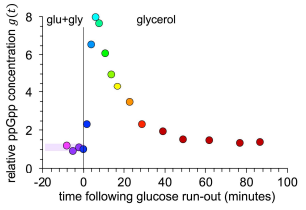
Scott et al. *Mol Syst Biol* (2014)

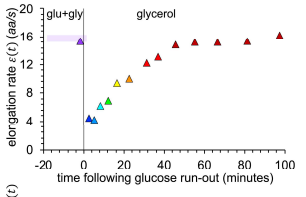
How is ribosomal fraction set?

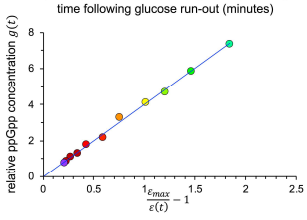






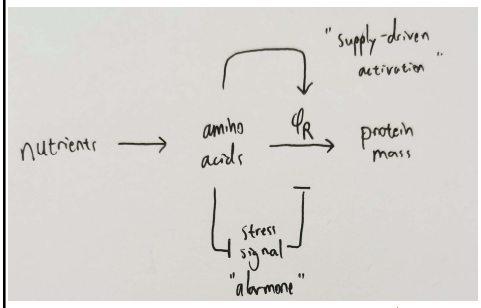


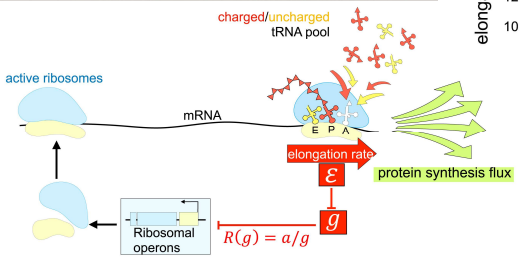


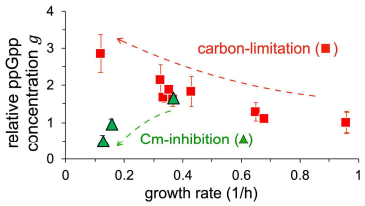


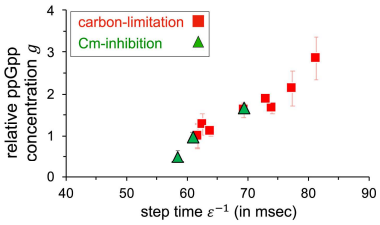
Wu et al. *PNAS* (2020)

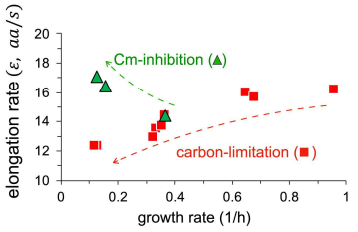
How is ribosomal fraction set?

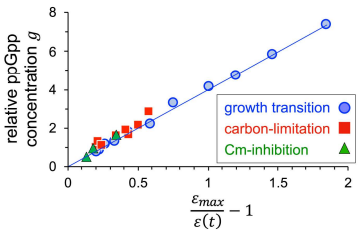






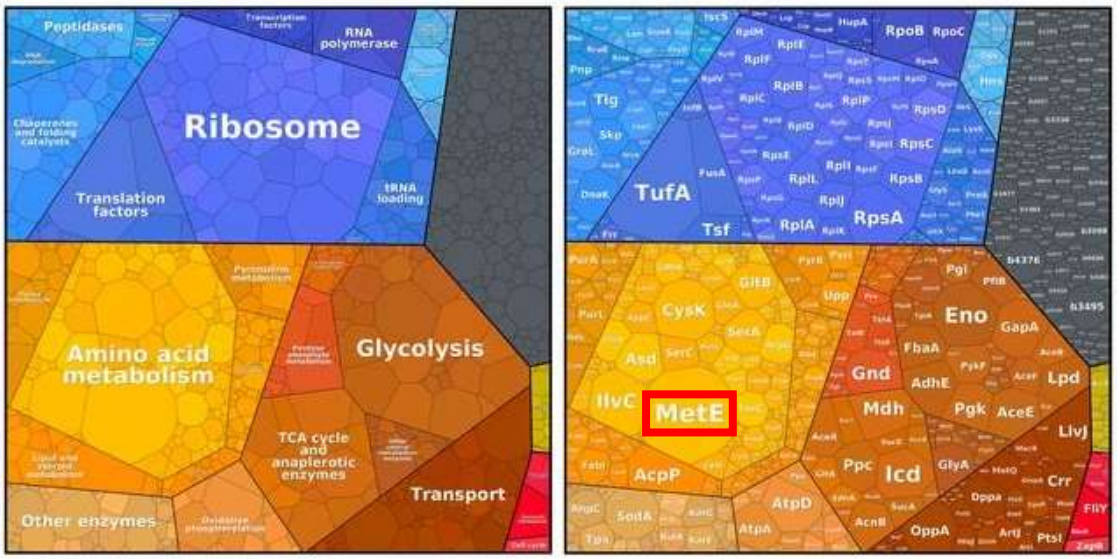






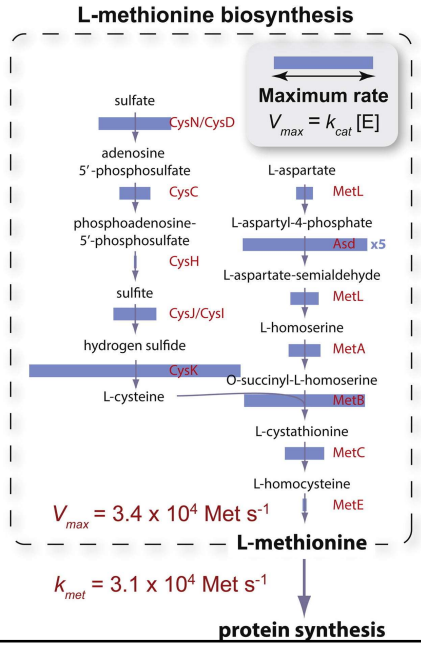
Wu et al. *PNAS* (2020)

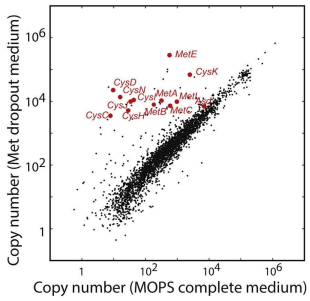
Proteome of an *E. coli* cell

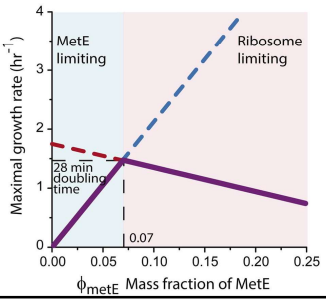


Liebermeister et al. *PNAS* (2014)

The proteome fraction allocated to methionine biosynthesis is optimal.







Gene-Wei Li et al. *Cell* (2014)