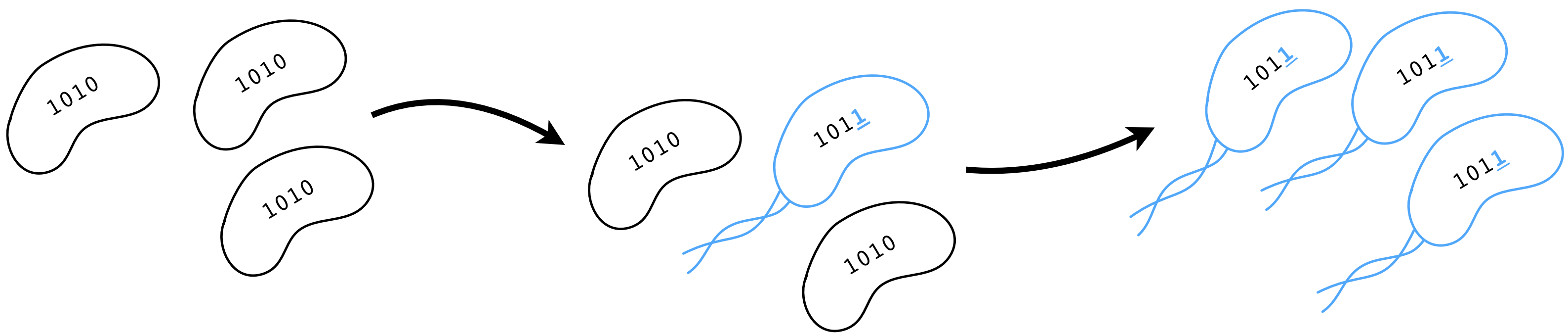
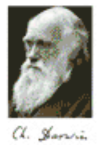
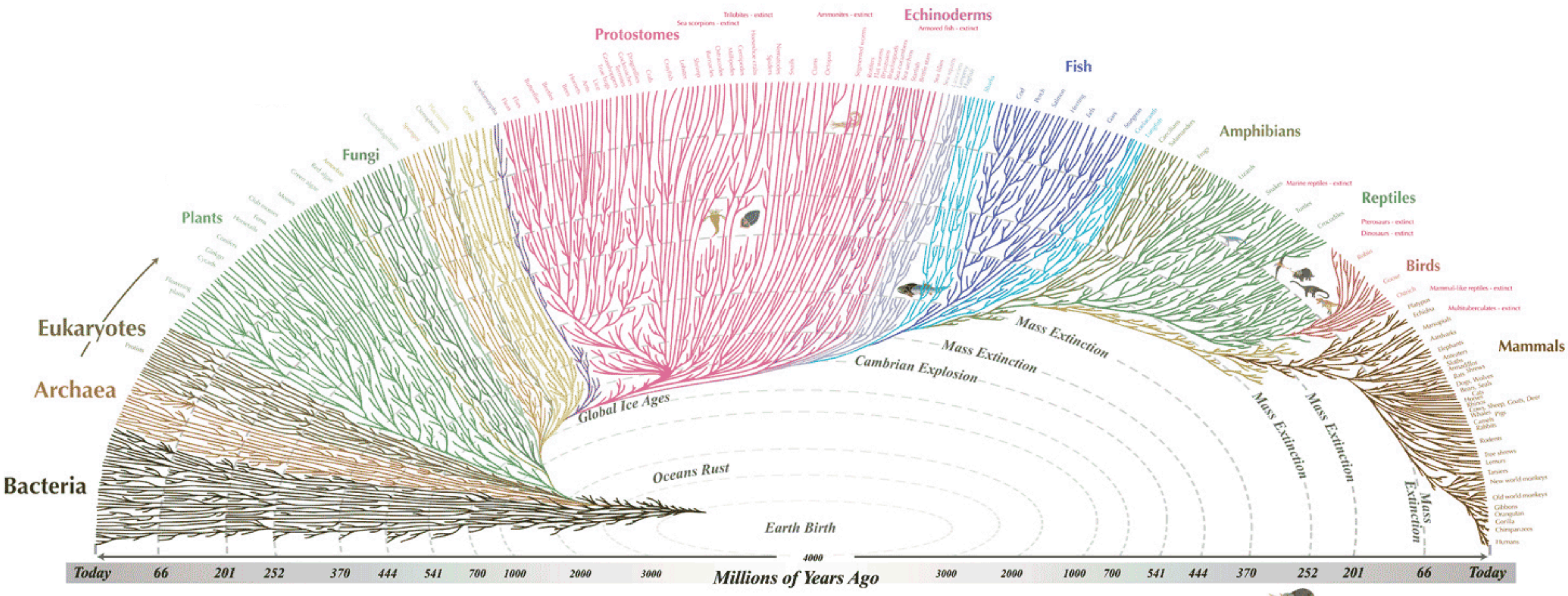
APPHYS 237 / BIO 251:
Quantitative Evolutionary Dynamics and Genomics



Evolution as an organizing principle



In 1858, Charles Darwin and Alfred Russel Wallace independently proposed a theory of biological evolution to explain the diversity of life on Earth. Since then the fossil record and DNA studies have added, and continue to add, overwhelming support for this view of life's history. Evolution today is one of the best documented and widely accepted principles of modern science.



All the major and many of the minor living branches of life are shown on this diagram, but only a few of those that have gone extinct are shown. Example: Dinosaurs - extinct

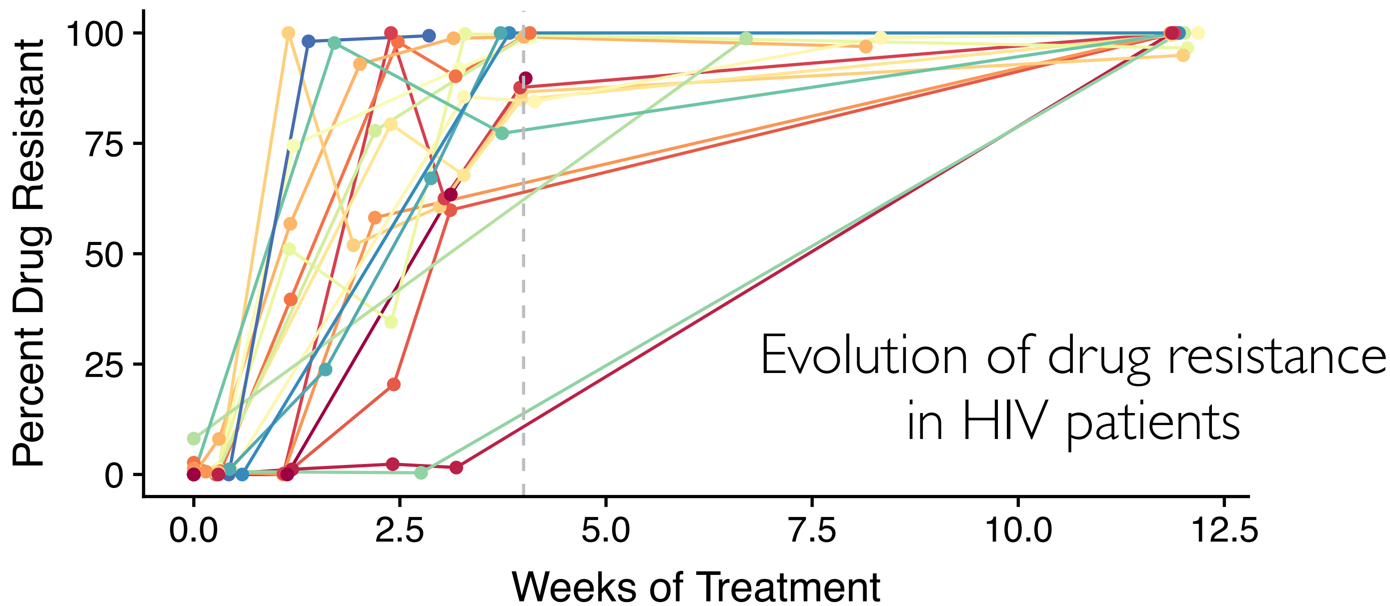
Evolution can produce exquisitely fine-tuned structures over long (geological) timescales

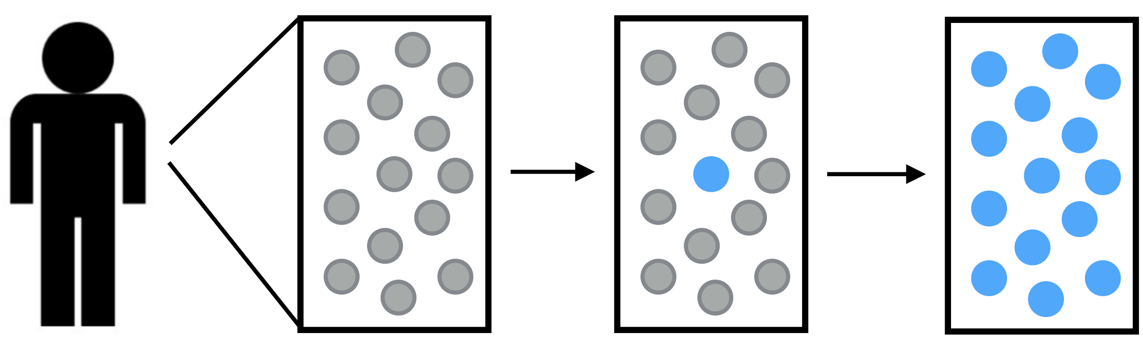
The Jurassic Park Theory of Evolution

"Life, uh, finds a way…"

Constrained by biological mechanisms & historical contingency
not clear how physics could help predict this

Evolution can also occur on *human-relevant* timescales in fast growing microbial populations

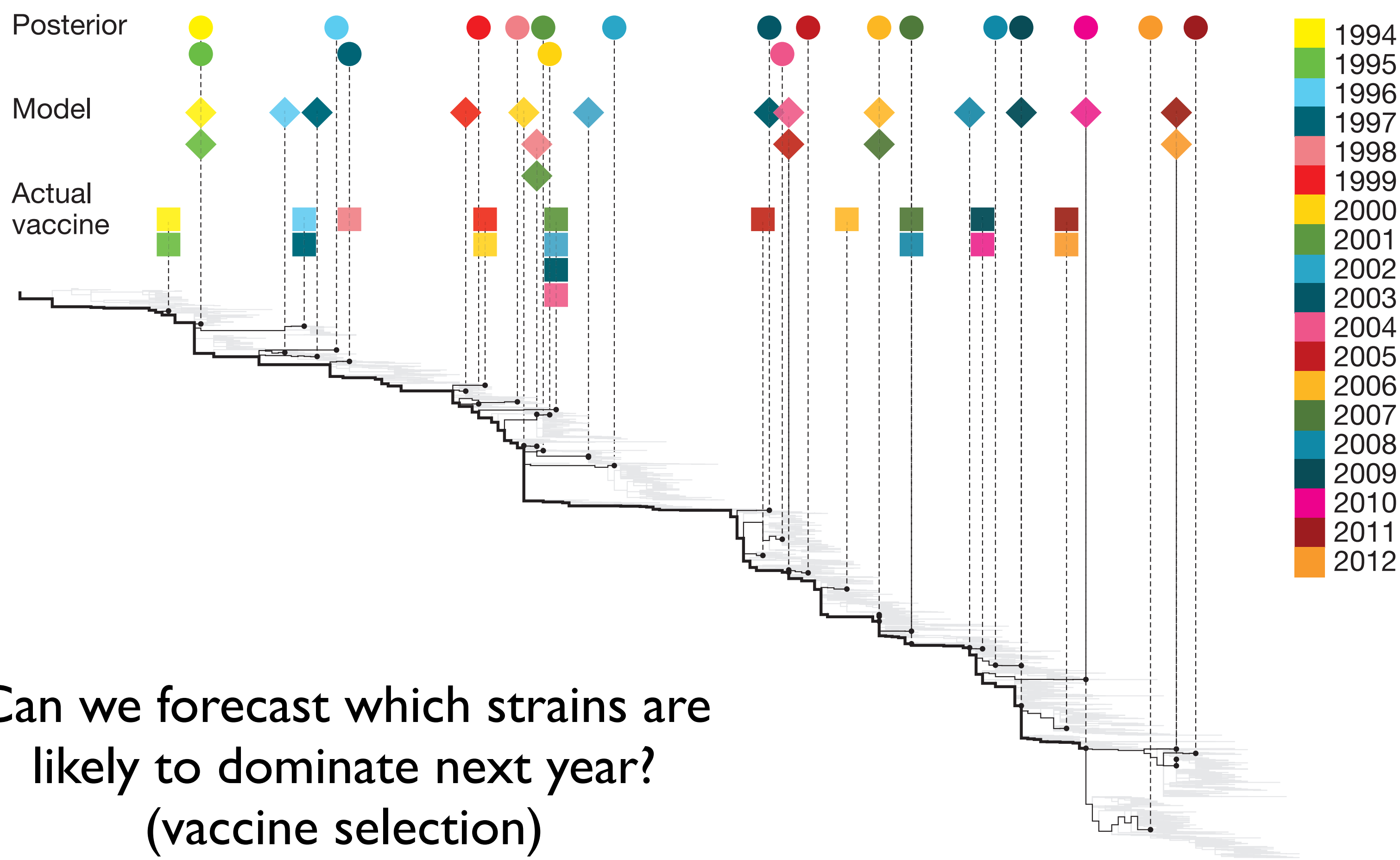




$\sim 10^9$ virus particles / host

(Figure credit: Alison Feder, UC Berkeley)

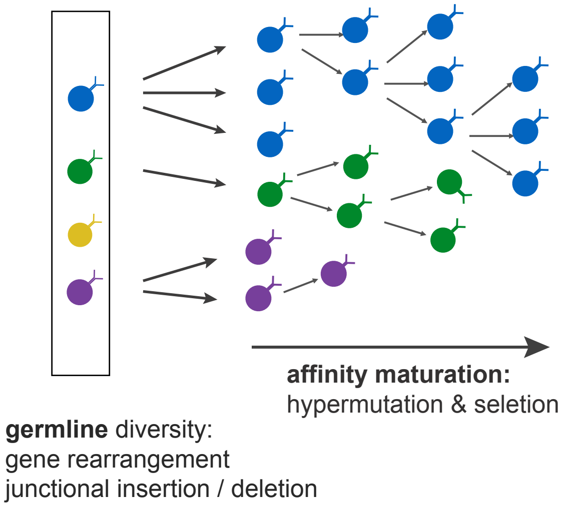
Example: antigenic evolution of the global influenza pop'n

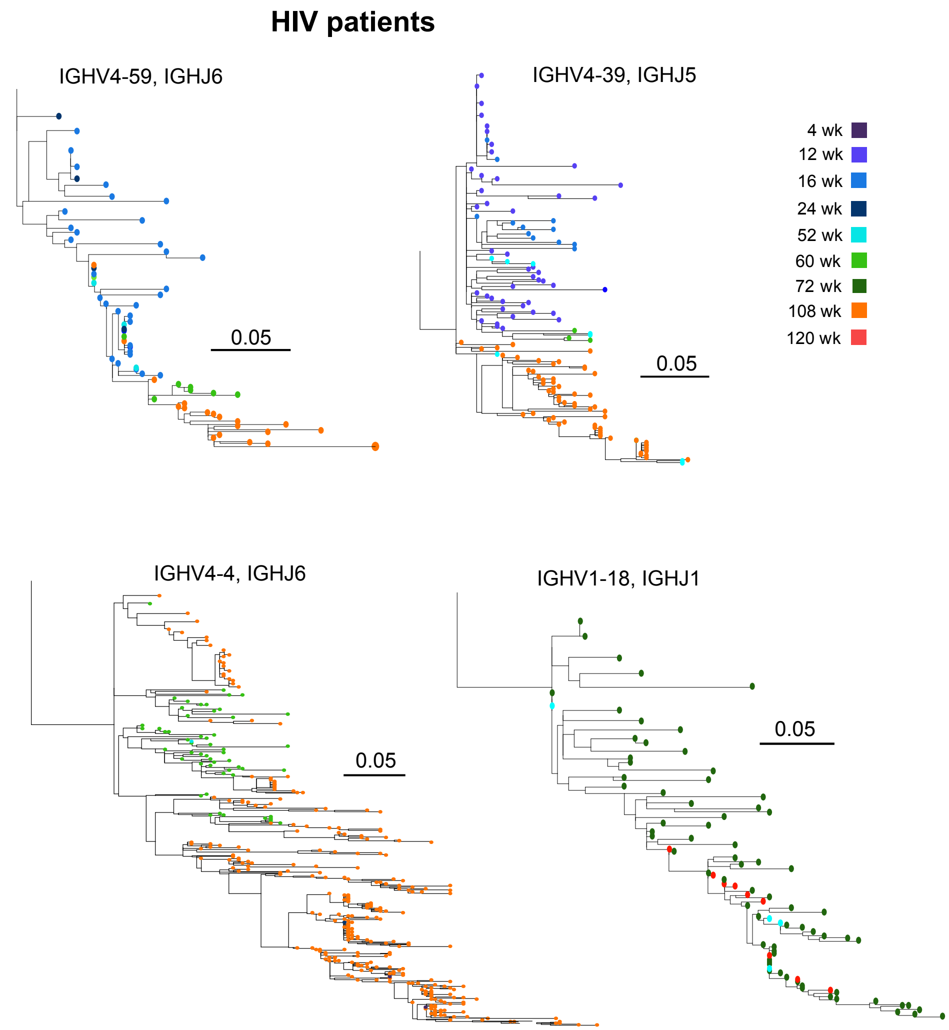


Can we forecast which strains are likely to dominate next year? (vaccine selection)

Luksza and Lassig (Nature, 2014)

Example: somatic evolution of immune repertoires

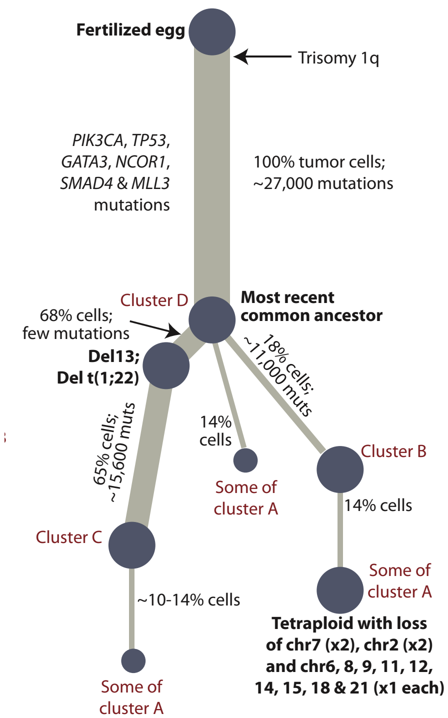


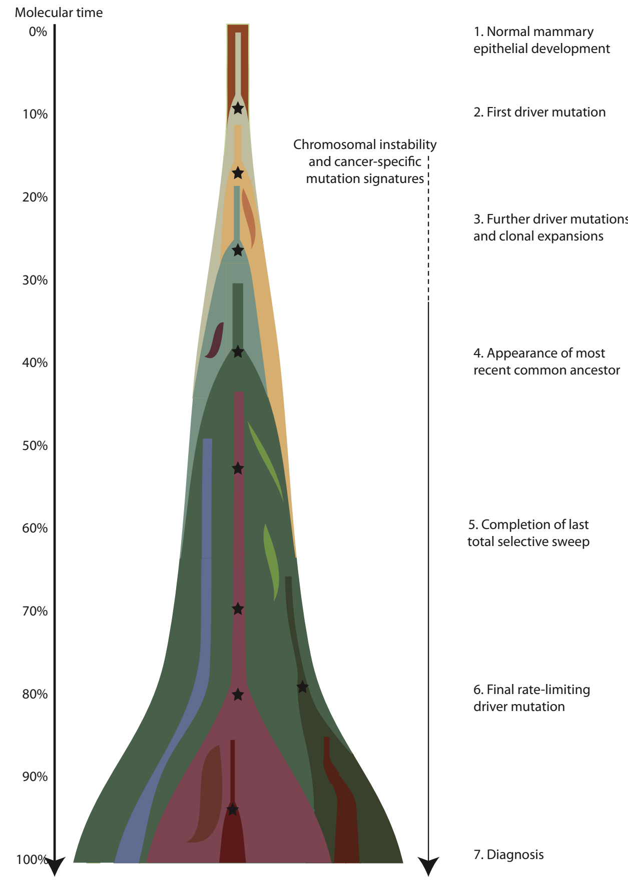


Can we guide the evolution of specific antibodies with the right vaccination strategy?

Nourmohammad et al (MBE, 2019)

Example: somatic evolution of cancer tumors

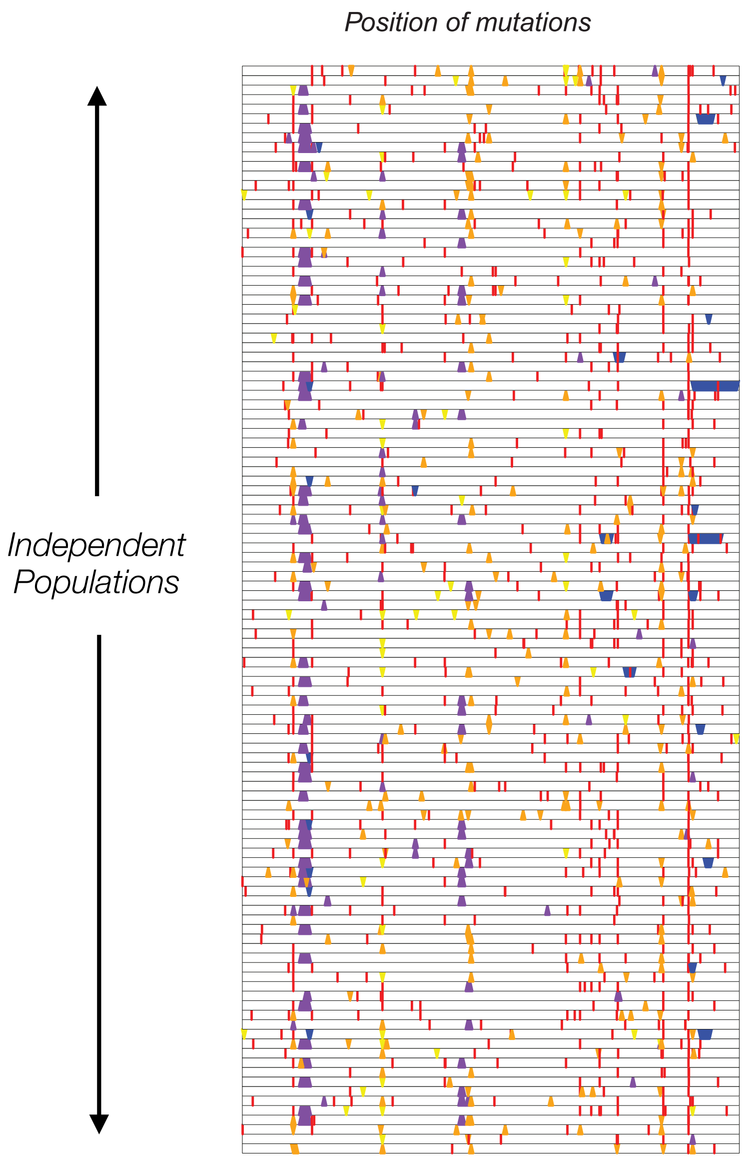




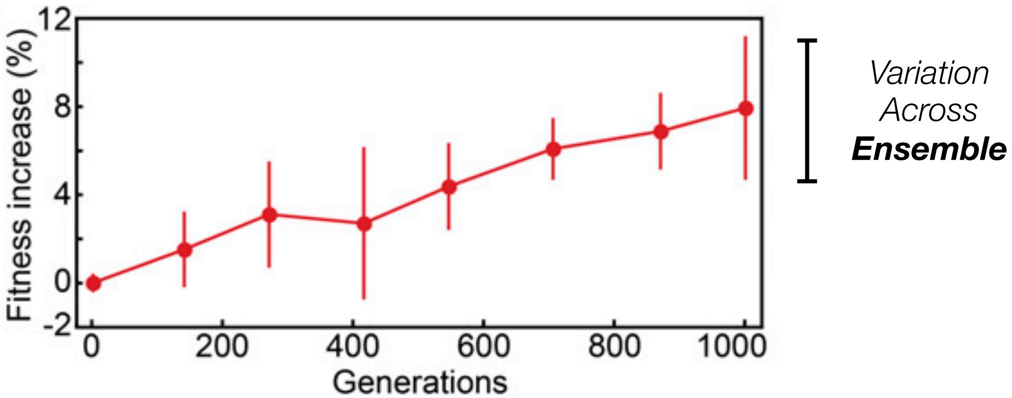
- How long does it take for cancer to emerge? 1 yr? 1000yrs?
- How rapidly do tumors acquire resistance to treatment?

Nik-Zainal et al (Cell, 2012)

Example: high-throughput evolution in the laboratory

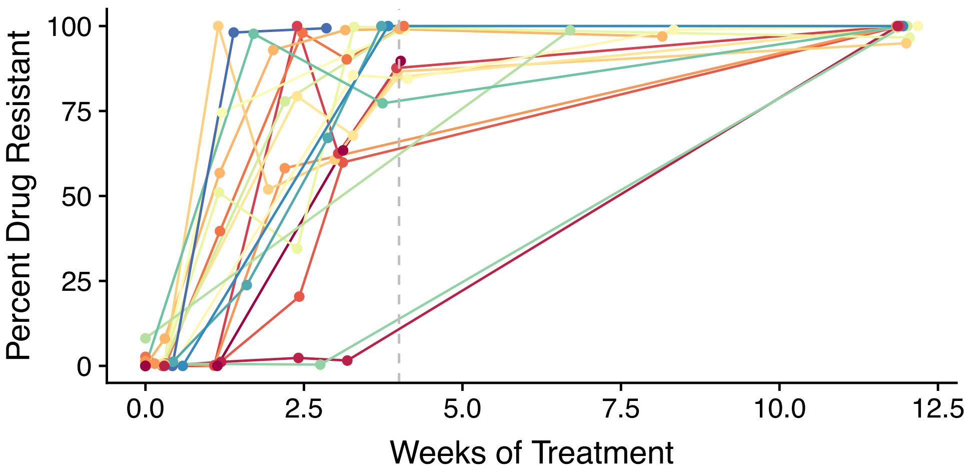


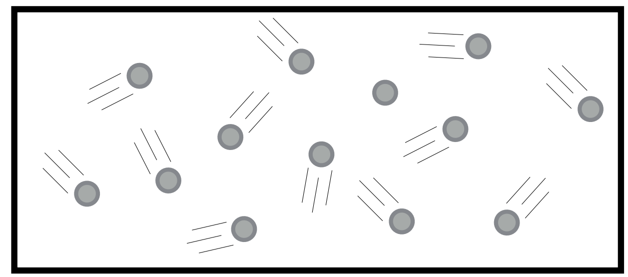
Tenaillon et al (Science, 2012)



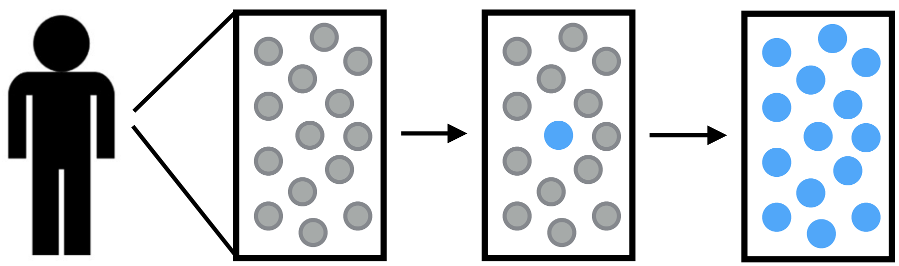
Lang et al (Genetics, 2011)

Evolution as a statistical mechanical process

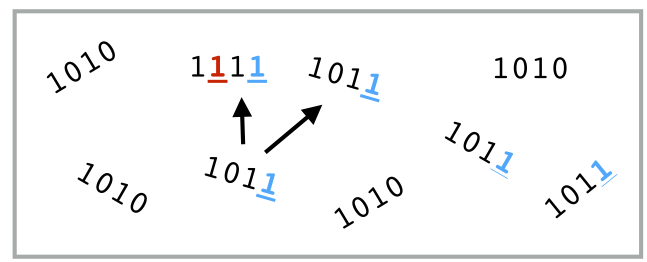




$$PV = nRT$$



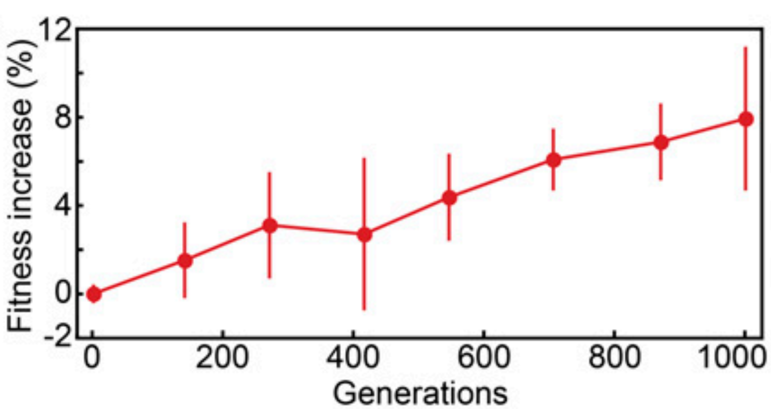
$\sim 10^9$ virus particles

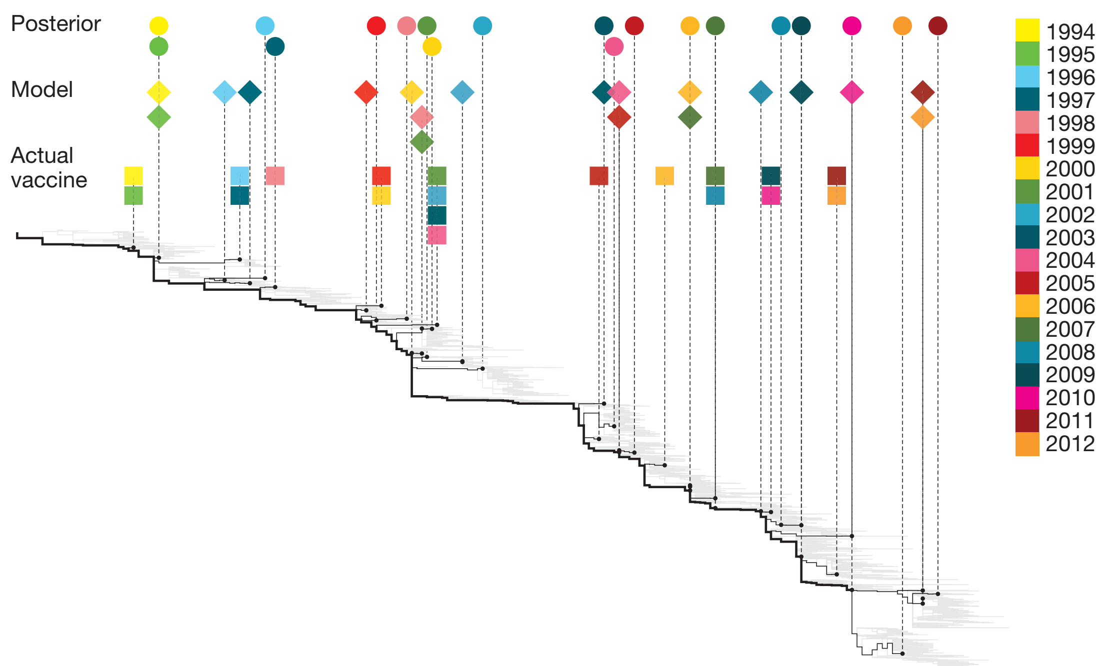


Goal: understand the ***mathematical models*** and ***experimental data*** that help us think about this process in a quantitative way

Papers referenced in previous slides

- Feder *et al*, "The clarifying role of time series data in the population genetics of HIV," *biorXiv* (2018)
- Luksza & Lassig, "A predictive fitness model for influenza," *Nature* (2014)
- Armita Nourmohammad *et al*, "Fierce Selection and Interference in B-Cell Repertoire Response to Chronic HIV-1," *Molecular Biology & Evolution* (2019)
- Nik-Zainal et al, "The Life History of 21 Breast Cancers," *Cell* (2012).
- Tenaillon *et al*, "The Molecular Diversity of Adaptive Convergence," *Science* (2012).
- Lang et al, "Genetic Variation & the Fate of Beneficial Mutations in Asexual Populations," *Genetics* (2011)





Plan for next 1-2 lectures

1. Mathematical Preliminaries
2. Biological Background (basic #s)
3. A Simple Model of Evolution