The Role of Robustness in Phenotypic Adaptation and Innovation

Or how I learned to stop worrying, and love the Genotypes

Why do we care about Phenotypes?

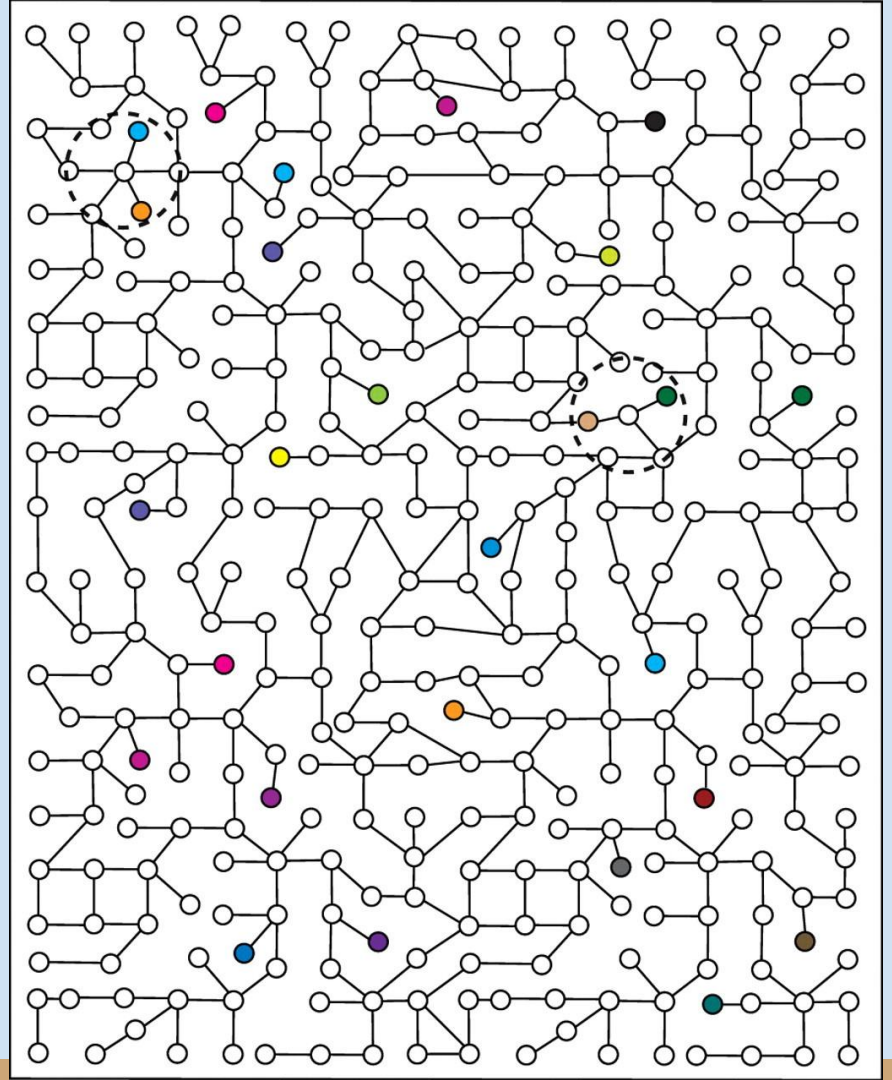
- Set of observable characteristics regarding an organism
- Influenced by Genotype (genes), and environment
  - Gene example: Eye color
  - Env. Example: Flamingo pinkness
- Phenotypes are “perturbed” by genotypes and environment
- Robustness is important; mutations are **bad**
  - Except when they’re not…
  - One of the main points of the paper

How do we get better?

- Organism populations want to have superior genotypes
  - Whose expressed phenotypes are better suited for the environment
- Superiority may be far away, and require “undoing”
  - Like solving a Rubix cube
- Solution: networks of different genotypes with the same phenotype
  - Ex: Macromolecules with oxygen-binding globins

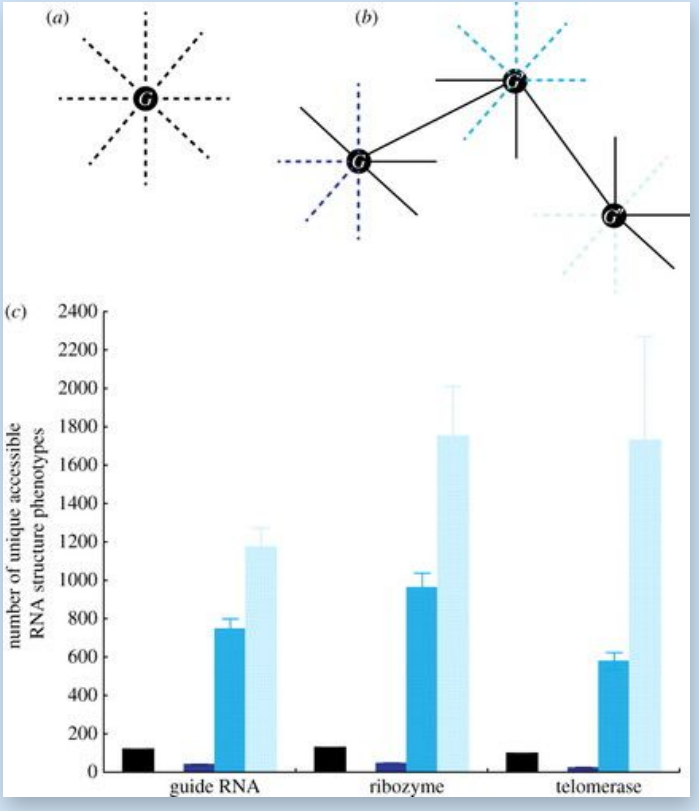
General Idea

- Mutations are **mostly bad**, but different genotypes producing the same phenotype is **good**
  - Producing the same phenotype is better for the **current** environment
  - Environmental perturbations force different genotypes to respond in different ways
  - Networks of genotypes are better suited to environmental changes, while preserving the same phenotype ensures success in the **current** environment

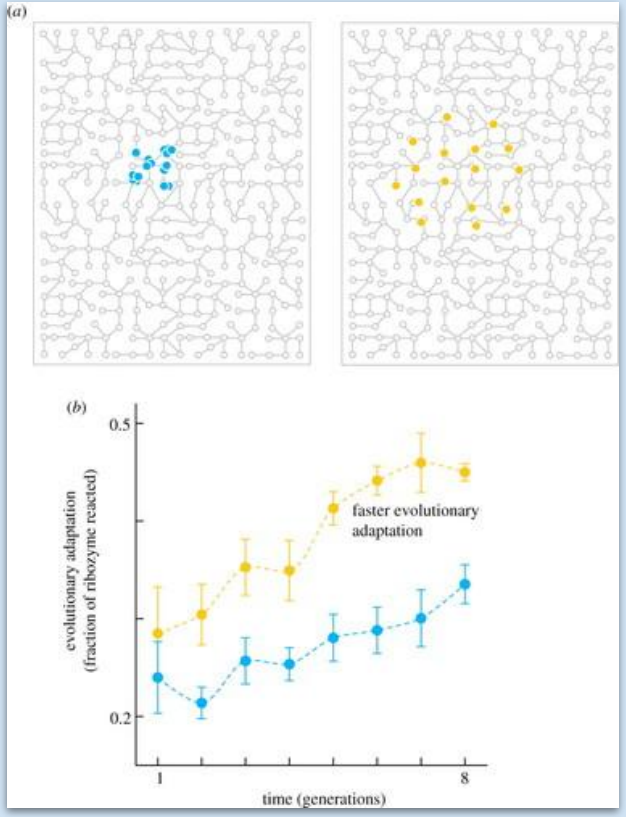


Minimally Robust vs. Moderately Robust Genotypes

- **Line types connecting neighbors**
  - Dashed: A neighboring genotype with a differing phenotype
  - Solid: A neighboring genotype with the same phenotype
  - Which has more phenotypic variability?
  - B = 4 + 5 + 4 = 13
- **New Accessible Phenotypes**
  - Shows accessible phenotypes for one, two, and three mutations away.
  - L is the number of nucleotides in the RNA
  - 3L is the number of accessible phenotypes after one mutation.
  - The guide RNA's network is actually 9.1x10^17 += 3.3x10^16



Cryptic Variation



- **Two lines of experimental evidence**
  - First Experiment
    - Involves one synthetic (self-ligating) and one natural ribozyme (self-cleaving).
    - 40 mutational steps to create a hybrid.
  - However, biological evolution does not use such premeditated paths.
  - Second experiment
    - Cryptic variation: genotypic variation that is not visible on the level of phenotype.
    - Experiment done with the same RNA, two different populations.
    - Population with more cryptic variation evolved 6 times faster.

Phenotypic variability affected by robustness

- Genotypes on a large genotype network are more robust to mutation than a small one.

- Two different phenomena effects on phenotypic variability
  - Number of different phenotypes in the neighbourhood
  - The rate of a population spreads through a genotype network

RNA Robustness and Variation

- **Two phenomena have opposite effects on variability**
  - High phenotypic robustness entails low variability in first phenomenon
  - High phenotypic robustness entails high variability in second phenomenon
- RNA secondary phenomenon dominant influence on phenotypic variability
- High robustness is associated with superior evolutionary adaptation
- Robustness can increase the ability of RNA and protein molecules to adapt in evolution

Robustness can help avoid conflict

- Conflict between “population” and “individual”

- How does Robustness help avoid conflict ?
  - RNA , poteins

Summary and Questions in the Field

- Two Roles of Robustness in Evolution
  - Existence of genotype networks
  - Accelerating dynamics of change, increasing exploration
- Remaining Questions in the Field
  - How do the sizes of evolving populations and their mutation rates interact with robustness to influence phenotypic variability?
  - Does robustness evolve in a way that facilitates evolutionary adaptation and innovation? Does natural selection favor robust phenotypes?