Natural Selection with Objective Imprecise Probability

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1. **Natural selection sometimes produces patterns of behaviors in members of species S_1 that are imprecisely probabilistically distributed, conditional on perceived environmental conditions; precisely calibrated, probabilistic behaviors are too costly.**
2. **These behaviors form part of the environment for members of another species S_2 (predators, prey, competitors, disease vectors, etc.).**
3. **So the S_2 population's environment includes imprecisely probabilistic conditions that can affect success in producing descendants.**
4. **S_2 is part of the environment of S_1, S_3, etc.**
5. **Thus natural selection often depends on objective imprecise probabilities.**

Causal probability and erraticity

- *Causal probability*: Objective probability realized by a set of conditions, a *chance setup* (person tossing dice) producing outcomes, where manipulating some of these conditions (densities in the dice) manipulates probability and, usually, relative frequencies.
- I assume there are ways for causal probability to be realized by underlying deterministic dynamics, as is in dice tossing.
- *Erratic* setups have outcomes but don't realize probability of any kind, at the level of the setup. (What's the objective probability that the percentage of ink in pieces of paper in pockets of the next ten people who attend a talk at ISIPTA lies within such and such bounds?)
- Natural selection depends on probabilities of survival and reproduction for organisms with different traits *in an environment*. If environments varied erratically, these probabilities could be imprecise.

Behavioral imprecision (premise 1)

- Let environmental states have precise objective probabilities.
- Natural selection should favor traits producing optimal behaviors conditional on perceptions of environmental state.
- Behavior narrowly distributed around an optimum is expensive: Nervous systems, muscles, bone, etc. require time to build, and energy to maintain.
- Good, imperfect: Probabilistic behavior, miscalibrated mean.
- Good enough, less perfect: Imprecisely probabilistic behavior.
- Note: If our behavior doesn't result from precise credences and utilities, why should organisms be better?

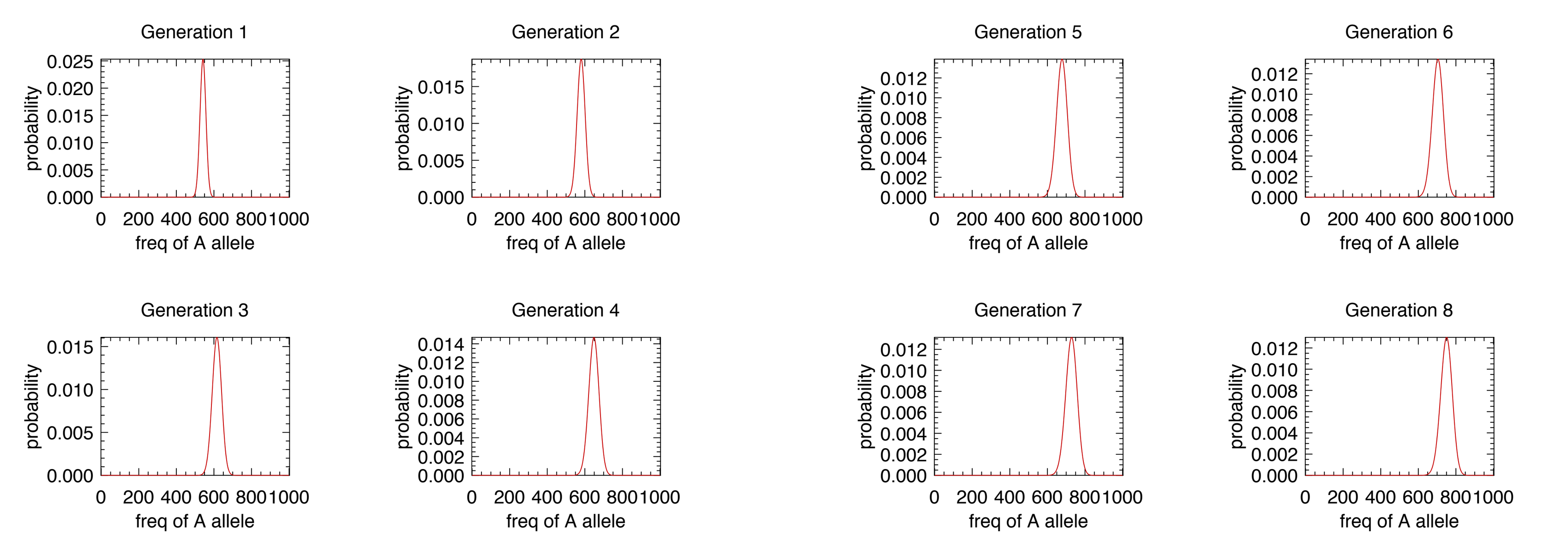
Imprecise fitness and decision rules

- Trait d: dig deep burrows, fitter in dry periods
  Trait s: dig shallow burrows: fitter in wet periods
- Fitness $w(x)$ for $x = d, s$ in environments e: $w(x) = \mathrm{E}_e\, w_e(x)$.
- If environments vary erratically: lower/upper (objective) previsions, infimum $\underline{w}(x)$, supremum $\overline{w}(x)$ precise fitnesses.
- Trait A_1 is fitter than trait A_2 *if* A_1 *interval dominates* A_2: $A_1 \sqsupset A_2$ iff $\underline{w}(A_1) > \overline{w}(A_2)$.
- Trait A_1 is fitter than trait A_2 *if* environments vary erratically so that the entire population experiences the same environment at t, and A_1 *dominates across population-wide environments*:
  Then A_1 is fitter$_{dp}$ than A_2 iff $(\forall e) w_e(A_1) > w_e(A_2)$.
- Other decision rules don't seem relevant. e.g. E-admissible traits won't necessarily be selected for. These are traits such that there is some particular environment that makes all of them at least as fit as all other traits: $\{A_i : (\exists e)(\forall A_j)\ \mathrm{E}_e(A_i) \geq \mathrm{E}_e(A_j)\}$.

Im/precise Wright-Fisher models

Precise: Simple model of change in allele frequencies. (Precise) probability of transition from i to j A alleles: $p_{ij} = \binom{2N}{j}\eta_i^j(1-\eta_i)^{2N-j}$, where the (precise) probability of an A allele being chosen is: $\eta_i = \frac{w_{AA}i^2 + w_{AB}i(2N-i)}{w_{AA}i^2 + 2w_{AB}i(2N-i) + w_{BB}(2N-i)^2}$.

Here A is fitter than B, so probable frequencies of A increase, $w_{AA} = 1.0$, $w_{AB} = 0.95$, $w_{BB} = 0.7$:



Imprecise: Bounds on lower/upper probabilities for A frequencies, erratically determined environments using Hartfiel's hi-lo algorithm, $w_{AA}=1.0$, $w_{AB}=0.9$, $w_{BB}=0.3$; $w_{AA}=1.0$, $w_{AB}=0.3$, $w_{BB}=0.2$: