Fixation of a beneficial mutation

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Plan

- Introduction to a basic quantity
- Specific question, recent result

Basic Evolutionary Processes

- Natural selection
- Mutation
- Stochasticity (random genetic drift)
- Population structure (mating systems, ploidy, migration,...)

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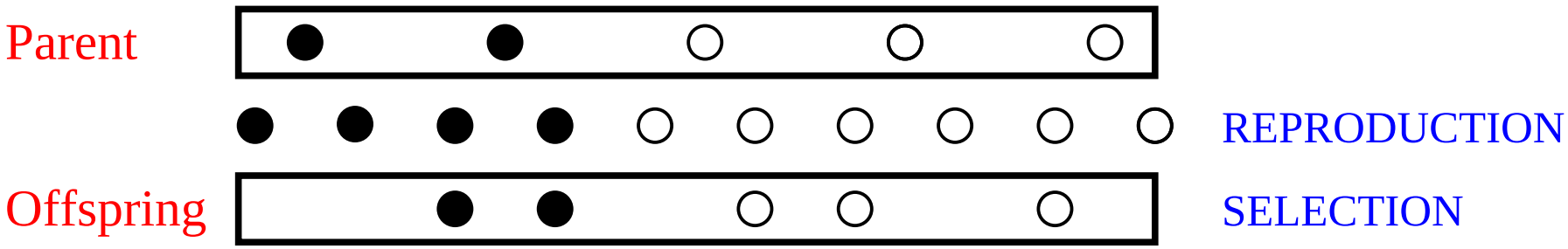
Random Genetic Drift

Each individual in the microbial population divides

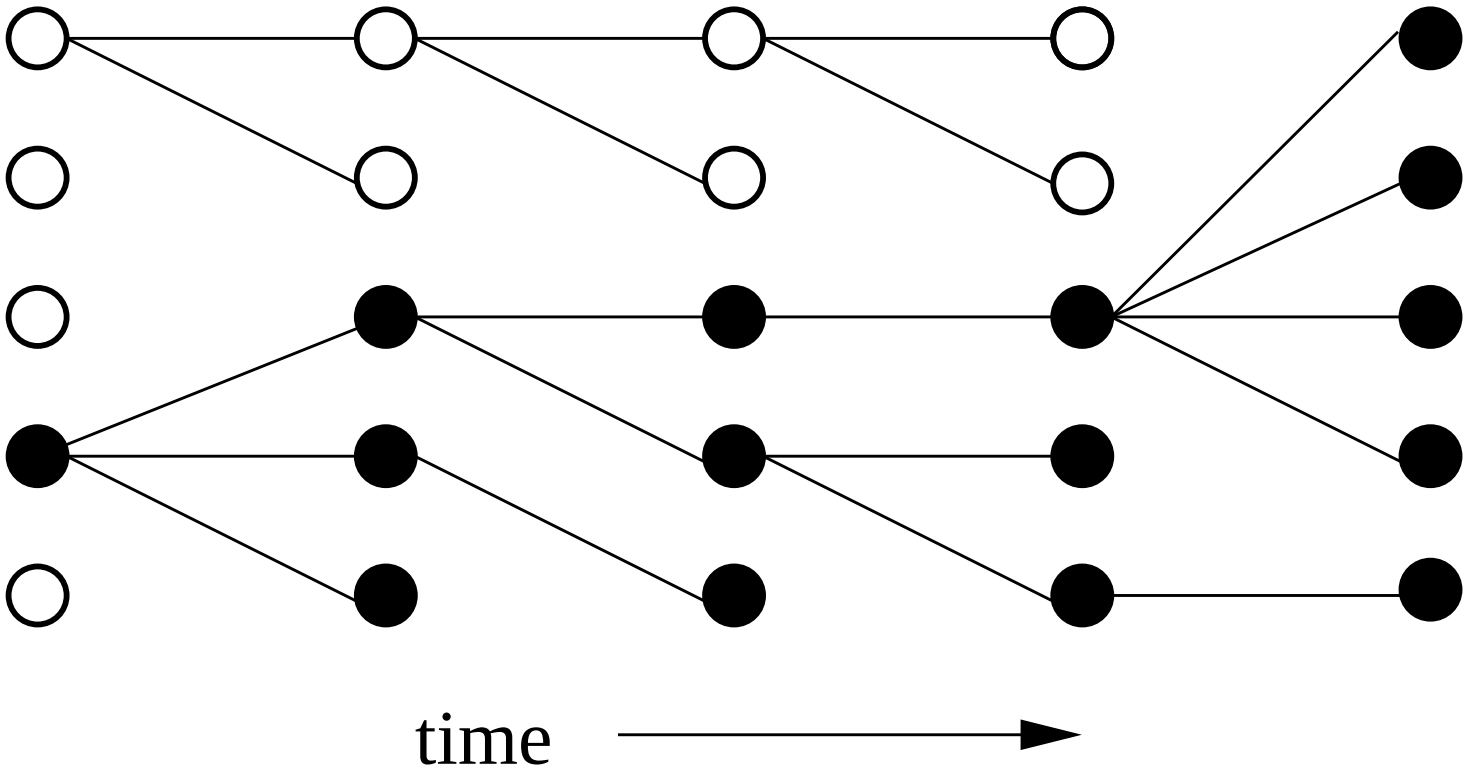


But resources are limited !

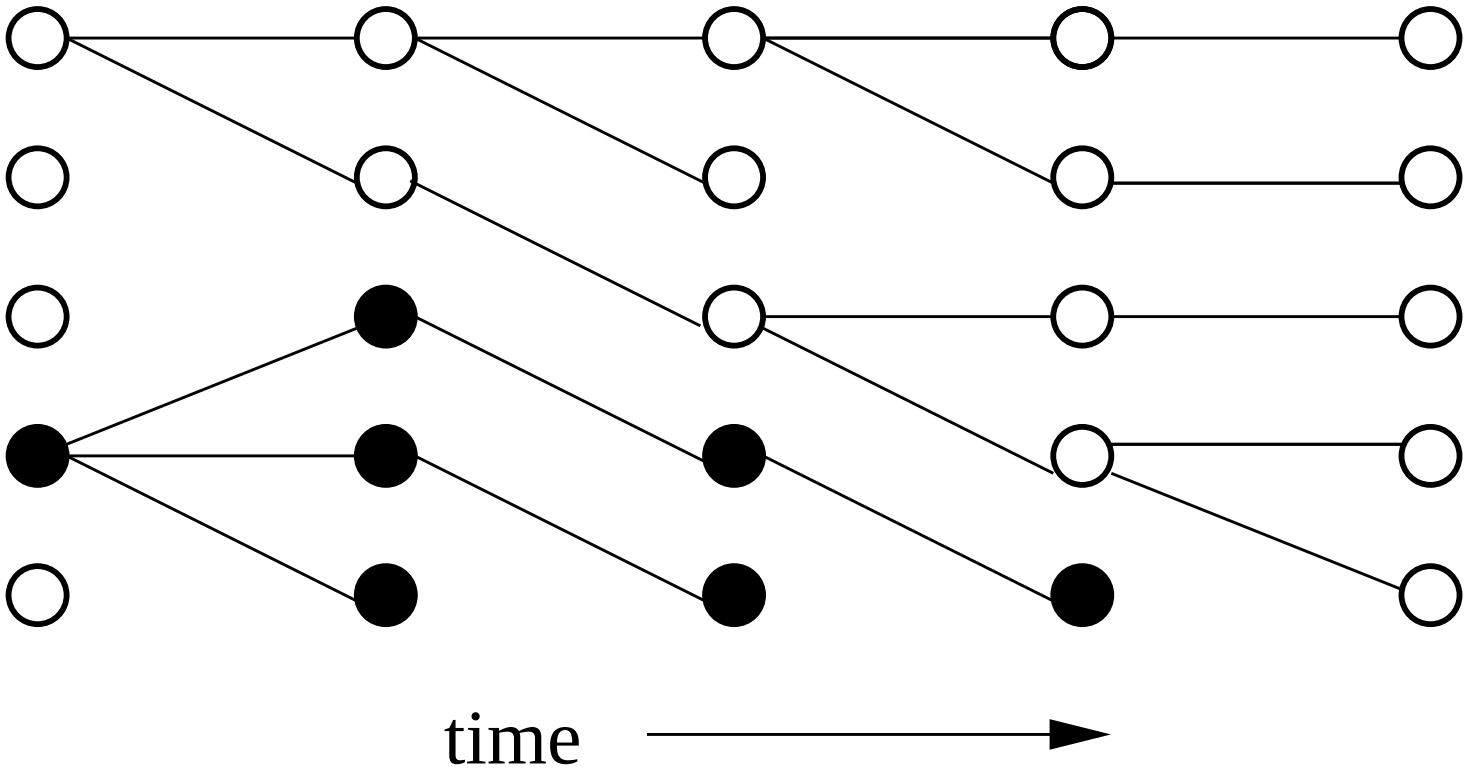
To maintain a finite population size, sample offspring with

$$\text{probability} \propto \text{fitness of parent}$$

Beneficial Mutation Spreads



Beneficial Mutation Lost



Moral (Kimura 1962)

- Beneficial mutations can get lost

- Deleterious mutations can spread

Fixation Probability

- What is the chance that the beneficial mutation spreads?

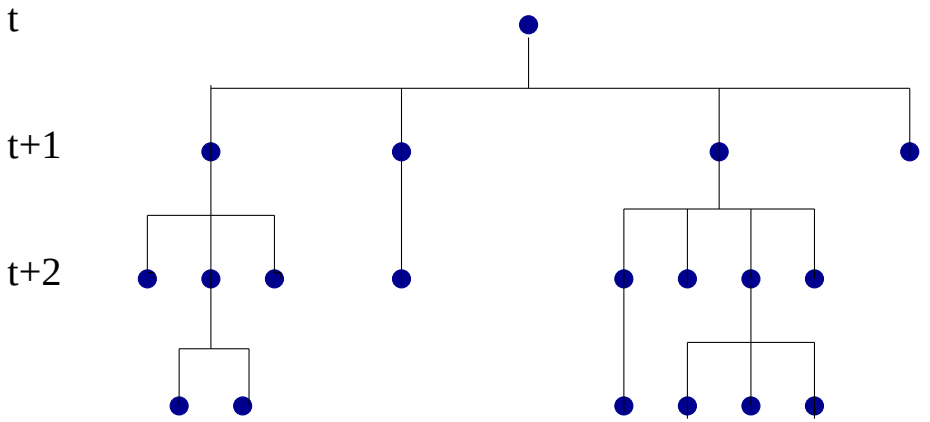
  P_{fix}=Prob(population in the absorbing states with all ●)

- Essential building block for complex stochastic models of adaptation

Backward Kolmogorov equation (van Kampen 1997)

$$-\frac{\partial}{\partial t_0}P(x,t|x_0,t_0) = \left[\underbrace{a(x_0)}_{\text{Deterministic}}\frac{\partial}{\partial x_0} + \underbrace{\frac{x_0(1-x_0)}{2N}}_{\text{Binomial sampling}}\frac{\partial^2}{\partial x_0^2}\right] P(x,t|x_0,t_0)$$

Branching Process (Harris 1963)



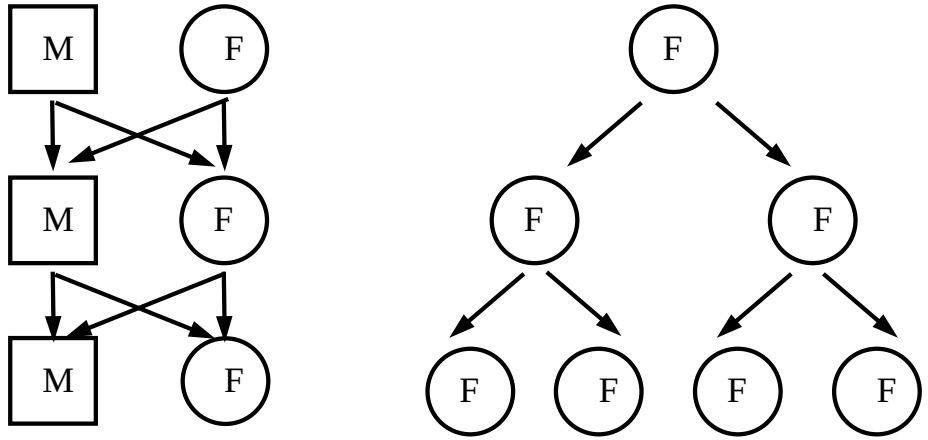
$$\epsilon(t) = \sum_{n=0}^{\infty} \underbrace{p(n)}_{\text{offspring distribution}} [\epsilon(t+1)]^n$$

Origin and Maintenance of Sex is... (Otto & Lenormand, 2002)

“one of the most enduring puzzles in evolutionary biology”

Why is sexual reproduction ubiquitous?

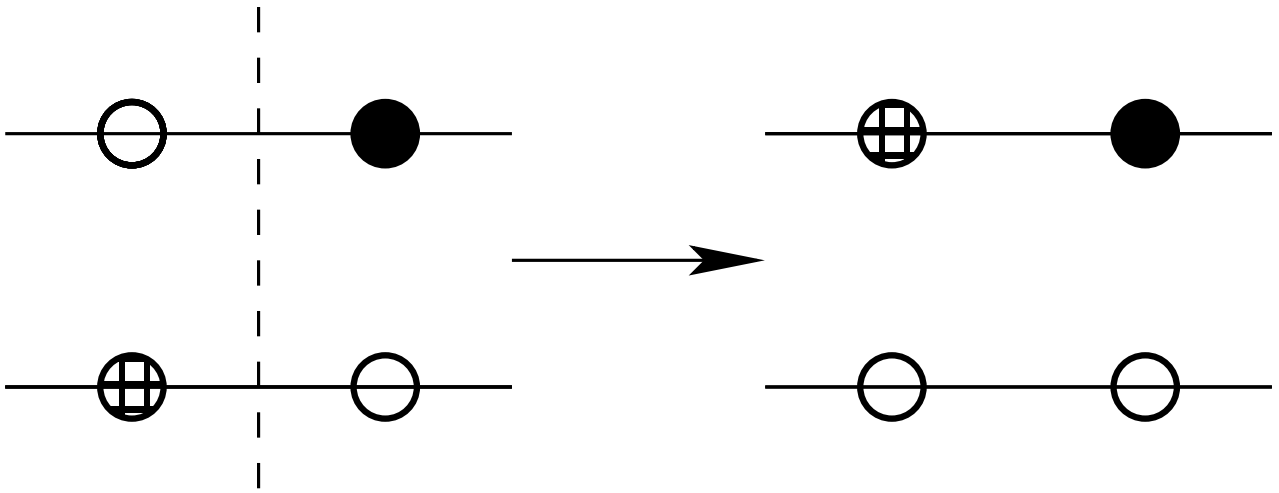
- Requires time and energy to find a mate
- Risky to produce an offspring by mixing genes (diseases)
- Two-fold cost of sex



Sexuals Asexuals

Fisher-Muller Argument (∼ 1930s)

Sexual population: favorable mutations can be combined



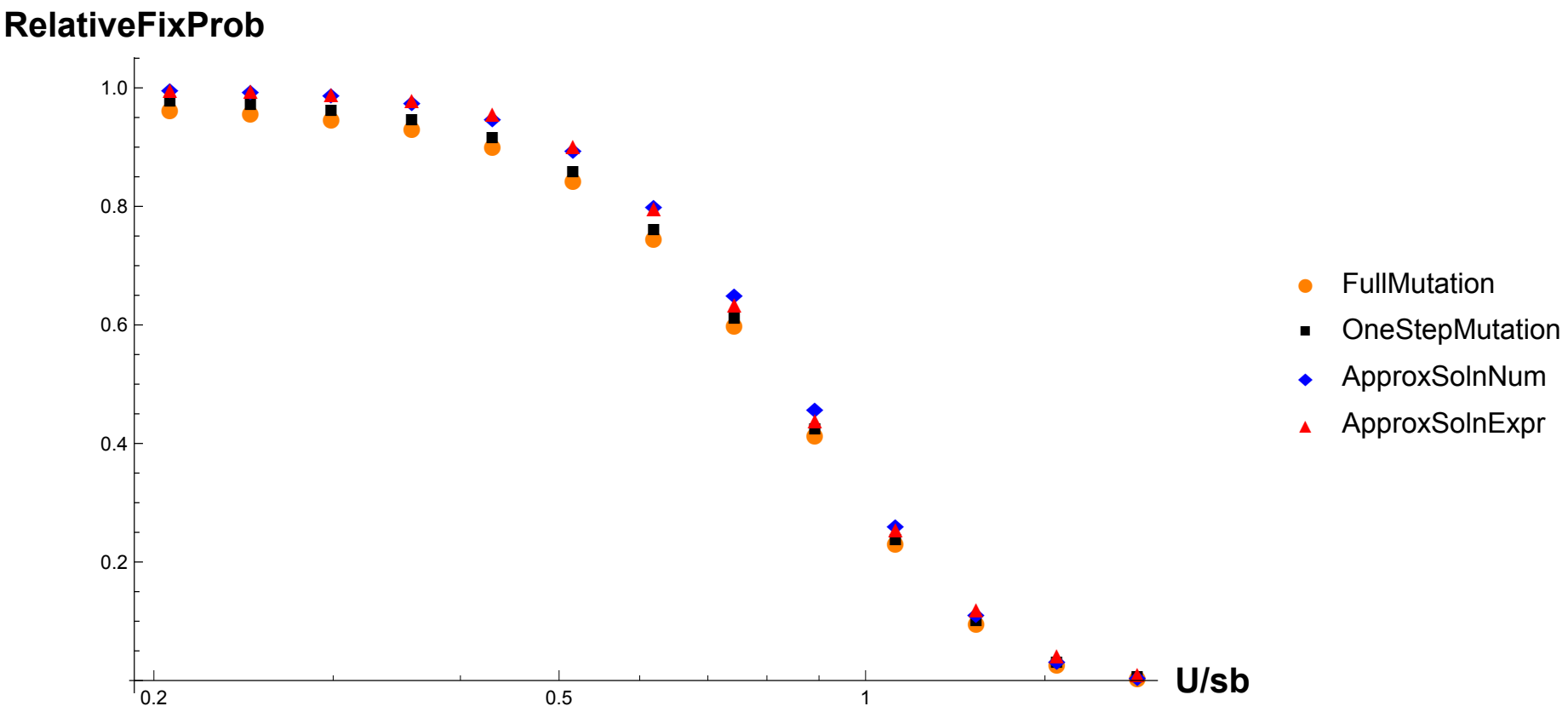
Asexual population: must wait for the next ‘hit’

Qualitative Argument $\rightarrow$ Quantitative Analysis

Beneficial mutation less likely to spread in an asexual population

$$P_{\text{fix}}(\text{asex}) < P_{\text{fix}}(\text{sex})$$

How much smaller?


RelativeFixProb
1.0
0.8
0.6
0.4
0.2
0.2
0.5
1
U/sb
FullMutation
OneStepMutation
ApproxSolnNum
ApproxSolnExpr

Summary

- P_{fix} : essential building block for complex stochastic models of adaptation

Need analytical expressions !

- Several other factors need to be accounted for; possible to build upon this