Population expansions and the wavefront effect

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Introduction

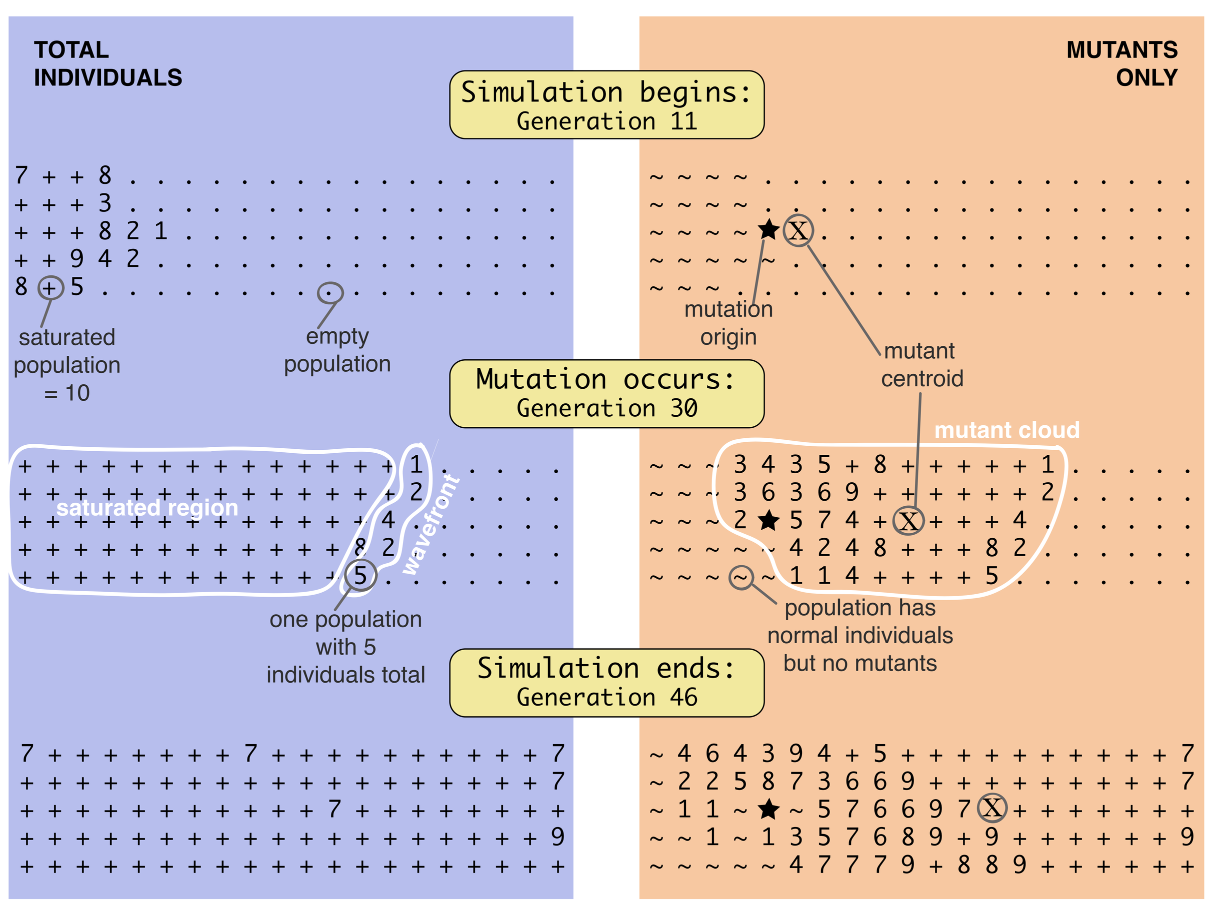
Human populations have had many demic expansions in the course of their radiation to the whole world, starting from a small initial population in East Africa. Here we use computer simulations to study the fate of mutations that occur in the wavefront of an expanding population. The **wavefront effect** we observe is quite dramatic, and is likely to have had a strong influence on mutations in past human expansions.

We first test the hypothesis that mutations that arise in the wavefront have a better chance of succeeding than mutations that arise in saturated areas. The **wavefront** is defined as the edge of expansion of a population. A **saturated region** is a densely-populated area of an expanding population. (See example below.) In our simulations, a **"successful" mutation** is one that is still represented at the end of the simulation. Our simulations end when the entire population has expanded as far as possible.

Because we observe such a strong wavefront effect, we continue by investigating wavefront mutations in more detail. We examine the distribution of mutants that results from successful wavefront mutations, the sizes of populations along the wavefront, and the effect of migration rate on the wavefront.

Methods

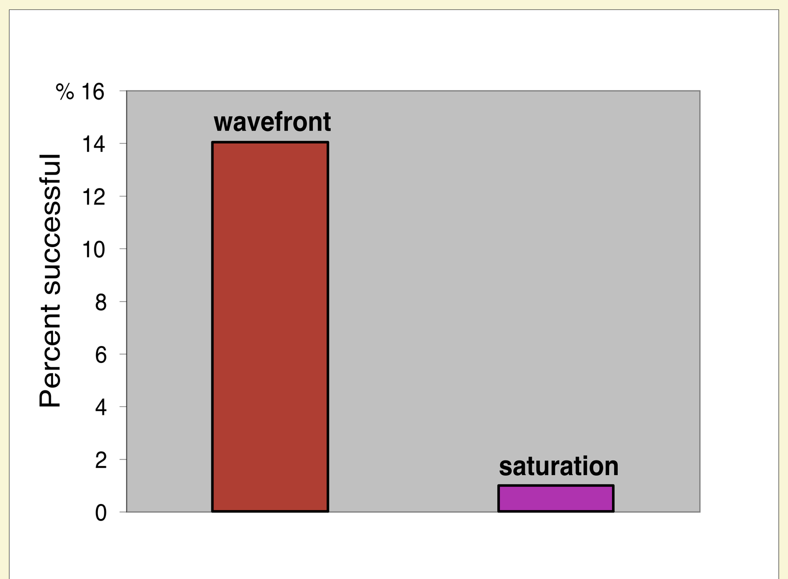
Two views of a simulation example



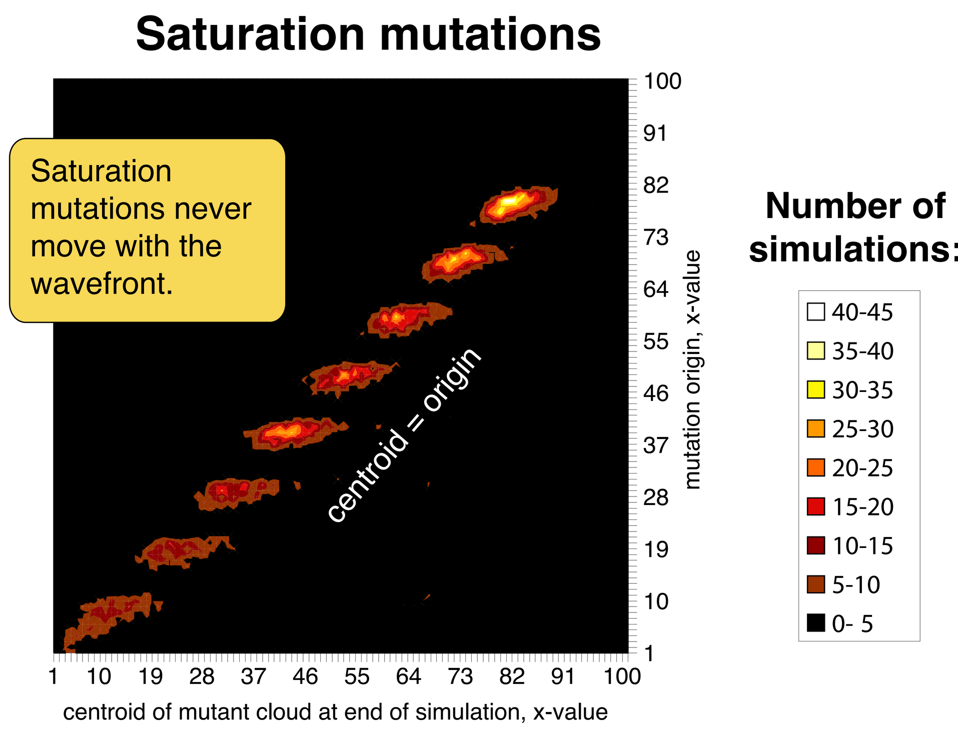
Note: For graphic clarity, this example simulation uses a 5 x 20 grid. Our simulations use a 25 x 100 grid.

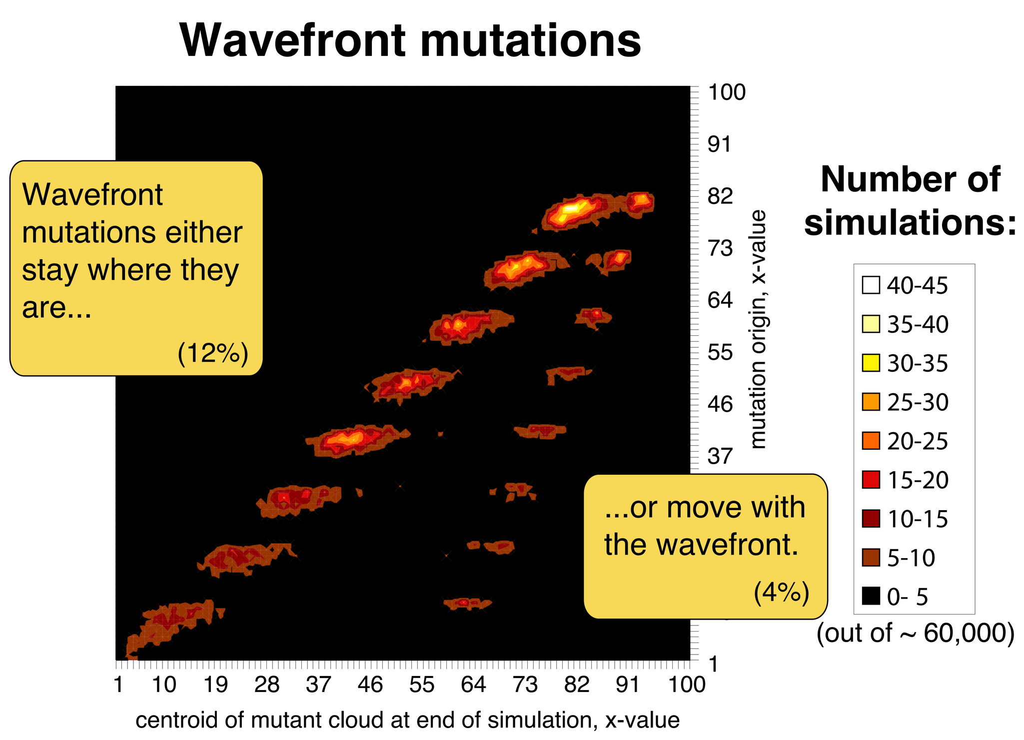
Results

Wavefront mutations are more successful than those that begin in saturation.

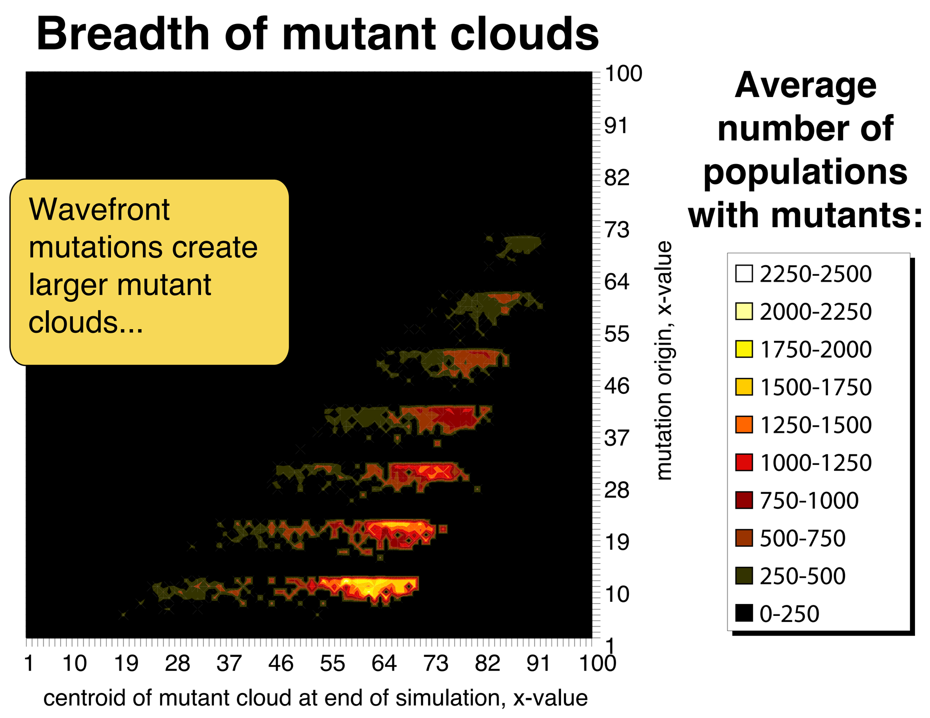


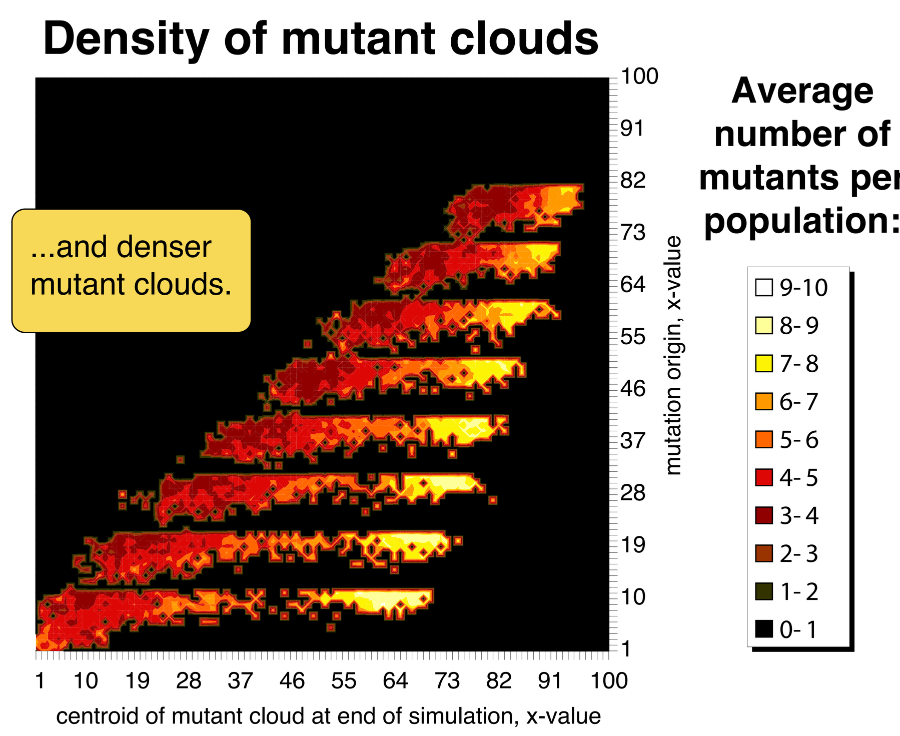
Summary of over 60,000 simulations:

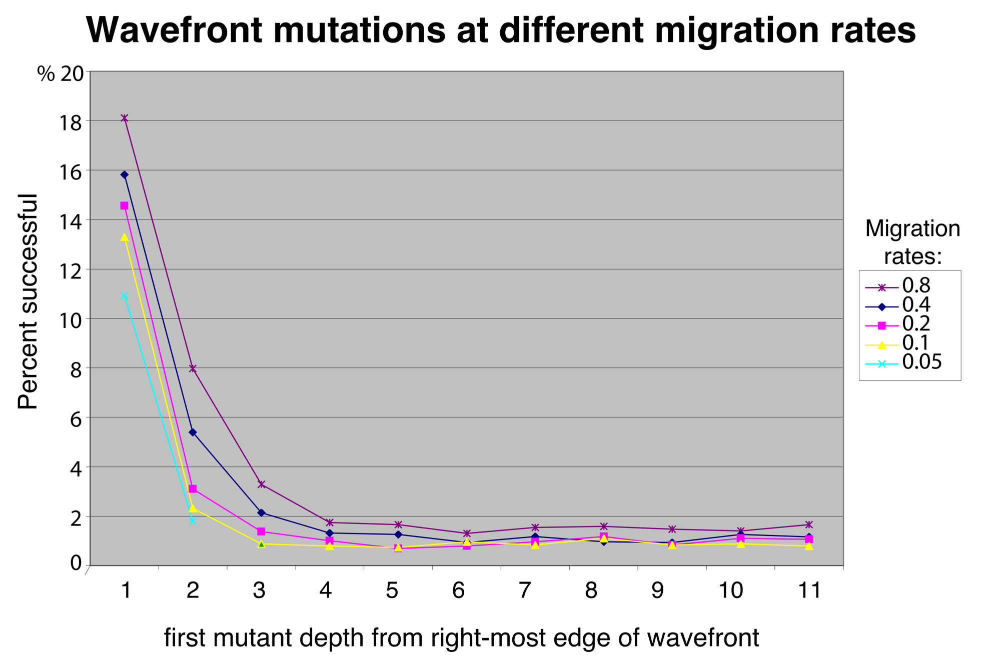




A closer look at the wavefront mutations...





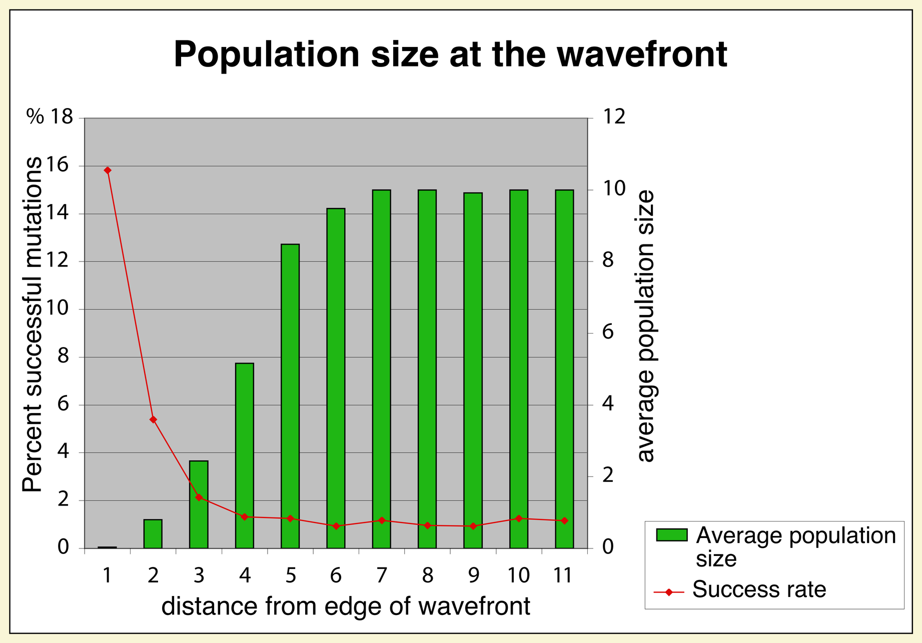


The migration rate affects the success rate and the width of the wavefront.

Higher migration yields higher success.

The closer to the wavefront, the smaller the populations.

These smaller populations are more successful as mutation origin populations.



Conclusions

SUMMARY: There is a **wavefront effect** in an expanding population, whereby mutations arising in the wavefront have a greater probability of being represented in the final population, and of moving away from their place of origin with the advancing population, than those which arise in saturated portions of the population.

Wavefront mutations “choose” either to generate a local cloud near their place of origin, or to travel much farther with the wavefront, creating a very large mutant cloud that extends from the mutation origin to the farthest extent of the wavefront. In these cases, the average location of the mutants (the **mutant centroid**) is about halfway between the place of origin of the mutation and the end of the expansion. Mutations that “choose” to stay and develop in the saturated region have a much lower success rate than those that travel with the wavefront.

The migration rate affects the wavefront population sizes, thus affecting wavefront mutation success.

The probability of success of a wavefront mutation depends on the number of individuals in the local population in which it originates. Mutations that first occur in smaller populations tend to have much higher success rates than those that start in larger populations due to an immediate high local mutant concentration (sometimes as high as 100%) and a bottleneck effect that follows. Since wavefront populations tend to be small, wavefront mutations tend to be more successful.