Experimental Evolution

A brief overview of how to set up evolutionary experiments

Revealing key mechanisms of evolutionary processes and understanding the intricacies of biological interactions leading to these key contributions, are desirable in the world of evolutionary biology. However, carefully dissecting the interplay between natural selection of mutations, and genetic drift, adaptation and population bottlenecks can be a treacherous undertaking. Observing the evolution of animals, such as Darwin's study on Galapagos finches[1], or geographically tracing hectors' dolphins[2], allows us to understand the main mechanisms. However, the inability to completely "re-start" evolution prevents us from truly understanding the magnitude of each of these key contributors to evolution. In 1988, Richard Lenski sought out to do exactly this[3], re-start evolution, by establishing his long-term evolutionary experiment. He has since been able to observe and answer some of natural selections' peculiarities, such as the pace at which mutations accumulate, and the likelihood of random mutations becoming of benefit and settling in populations. Lenski's pioneering experiments have allowed us to draw hope that perhaps one day, we can understand our origins. This primer seeks to provide a brief overview of how to set up evolutionary experiments to allow a wider population to provide explanations for some of evolutions mysteries.

Mutation accumulation experiments

Depending on what the purpose of the evolutionary experiment is, the type of experiment will differ. When wanting to study dynamic genomes, such as viruses, transposable elements or repetitive elements and their mutation rates, a mutation accumulation set-up will likely be a good choice. In mutation accumulation experiments (Fig. 1), mutations of clonal populations are observed. Here, the original population is grown on agar plates and re-streaked onto a new plate, purposely inducing a bottleneck. This process is then repeated several times with time-points of repetition determined by the researcher, such as the generation time of a particular number of generations. This singular or repeated process causes a significant loss of genetic diversity and, at the same time, prevents selection of the fittest. Thus, upon analysis, mutation accumulation experiments allow an estimation of rates for spontaneous mutations.

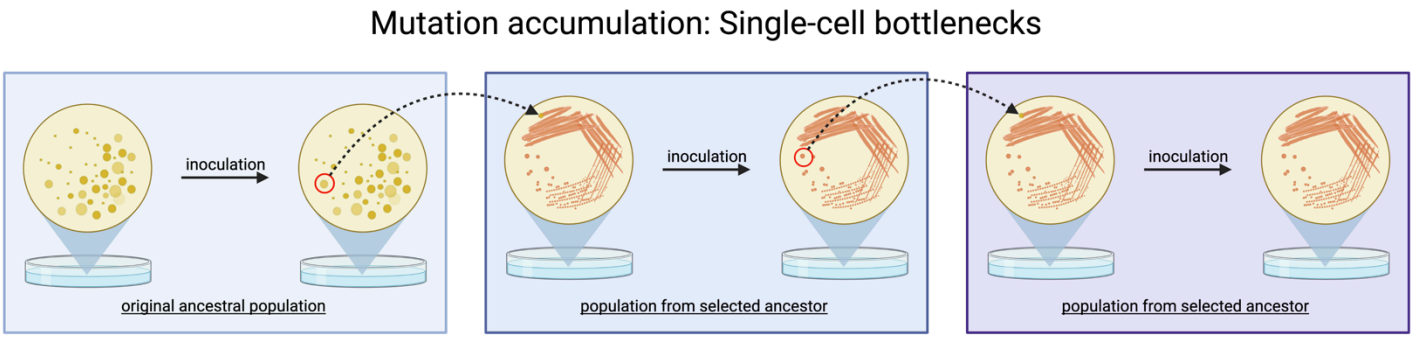

Figure 1: Experimental set-up for a mutation accumulation experiment, generating a single-cell bottleneck.

Adaptive evolution experiments

Studying adaptive evolution should be undertaken in experiments that mimic natural selection. Here, the intention is to encourage the survival of the "fittest" in a particular environment which is determined by the researcher. This may take place in one of two ways, and both ways are undertaken in liquid culture.

Continuous culture: In a continuous culture (Fig. 2), the organisms remain in the same culture with the help of a chemostat. The conditions within the chemostat are maintained by a steady replenishment of nutrients from one end, the implementation of environmental conditions selected by the researcher, and an effluent of waste and random individuals. This type of adaptive evolution experiment allows for a steady population size independent of time, though the removal of individuals that are not part of the chemostat will generate a gap in the population akin to a selective sweep.

Serial transfer: The other type of adaptive evolution experiment is a serial transfer (Fig. 3A). In this experimental set-up the population is grown to a certain time point determined by the researcher, or perhaps when the nutrient sources are exhausted,

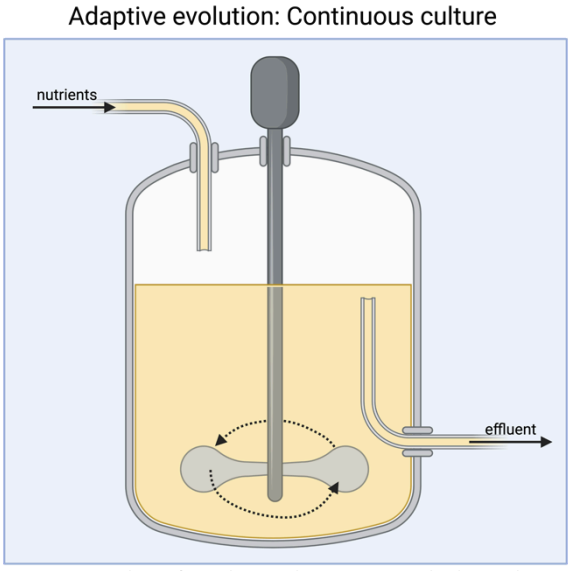

Figure 2: Experimental set-up for an adaptive evolution experiment, undertaken in a chemostat as a continuous culture.

and a part of this culture is then transferred into a new flask with a fresh supply of nutrients. This cycle continues and allows for adaptive evolution over a long period of time with a significant drop in population size at each transfer timepoint. This experiment is also restricted by the selection of a "random" part of the population, which may invertedly encourage a selective sweep over a few generations. However, it also poses a huge advantage over all other evolution experiments, and this is perhaps what makes this type of adaptive evolution experiment the most appealing. This experimental set-up enables the researcher to take further sample populations from the flask without impacting the transfer population (Fig. 3B). The removed samples can be genomically analysed. They can be frozen, kept as stock for future experiments, or used for competition experiments between ancestral populations. They could even be cultured under different conditions to determine how a change in environmental conditions impacts the individual populations. Thus, this experimental set-up is likely the most useful in evolution experiments.

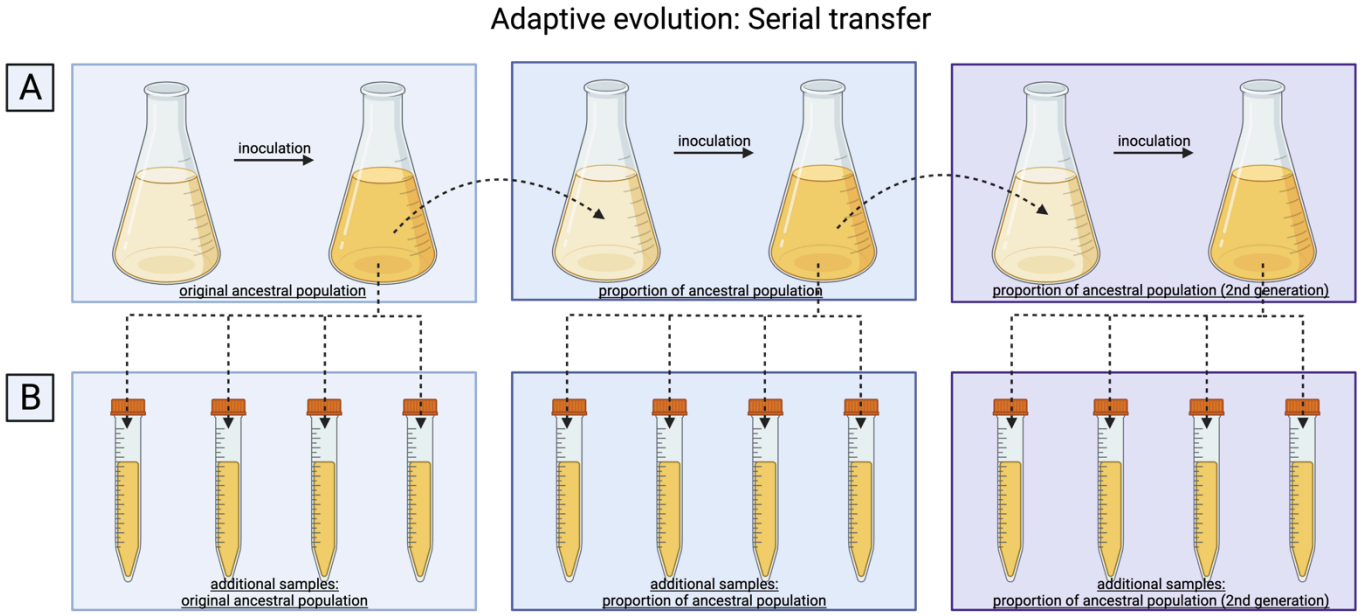

Figure 3: Experimental set-up for an adaptive evolution experiment in the form of a serial transfer.

Tinkering with adaptive evolution (experiments)

In any case, manipulations within the experiments can be undertaken to determine "natural" selection under particular growth conditions. Much like in the real world, where disruptions to our environment, for instance industrialization or the continuous loss of the ozone layer, impacts the conditions we are exposed to. Examples of manipulations can be changes in nutrient supply, such as limiting or oversupplying specific nutrients. Other changes enforced could be relating to environmental conditions, such as day/night cycles, other types of UV exposure, or generating spatial gradients to allow individuals to naturally develop mutations for specific niches.

Observational research in nature can only educate us on current, slowly occurring changes that are very likely going to outlive the researcher. Evolutionary experiments on the other hand establish evolutionary dynamics under controlled conditions in the laboratory. This method can educate us on evolution without competition from different species or kingdoms. Thus, it allows us to understand the key dynamics underlying evolution and enables us to apply our knowledge to what we observe outside of the laboratory.

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Acknowledgements

We thank biorender.com.

Further reading & references:

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