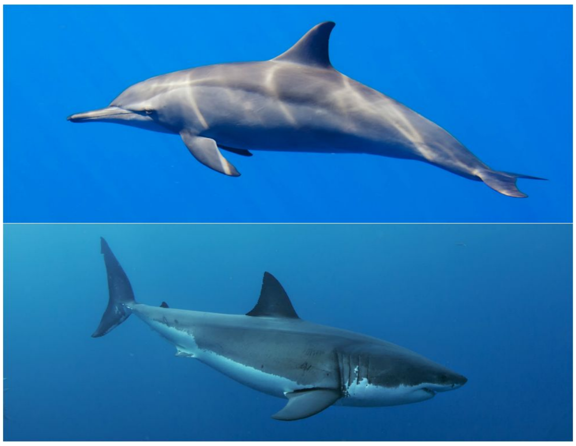
Student Handout: Recent research on *Aloe vera* showing application of ethnobotany, biogeography and phylogenetic studies

Introduction

The fact that we tend to be similar to our close relatives does not come as a surprise to most of us. From physical to personality traits, nature has left us wondering how much of our resemblance with our siblings is caused by genetics or the environment. When talking about the relatedness between species, the questions are still the same: Are these two species similar because of genetics (do they share a close common ancestor?) or because they experience similar environmental pressures (convergent evolution)? Regardless of what the answer may be for two determined species, it is widely accepted that closely related organisms share a variety of similar characteristics, from DNA and protein sequences to morphological structures and chemical properties. But as interesting as this topic may be, pragmatic questions also arise about the study of evolution: How can we use evolutionary information to the benefit of modern society?



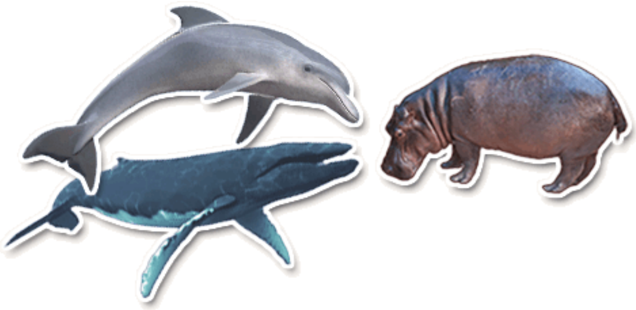


Figure 1. The similarities between sharks and dolphins can be explained by convergent evolution. Despite being distant relatives, the two animals experienced similar environmental pressures which caused them to show similar traits. DNA evidence shows that dolphins are actually more closely related to hippos, and their morphological differences can best be explained by divergent evolution.

Phylogeny and its applications: The case of *Aloe vera*

The reconstruction of the evolutionary history of organisms does not only bring us closer to understanding the processes of change in species, it also gives us an insight of which groups can provide us with a chemical of interest, or which species are more relevant to protect against climate change. It is known, for example, that the medicinal traits of plants usually run in families, meaning that a plant is more likely to have medicinal properties if it belongs to a clade, or monophyletic group, that presents organisms with such properties. This is because closely related species tend to share major metabolic pathways, which results in the properties observed. However, not all species in a clade will have the medicinal properties beneficial to human societies, which is partly due to divergent evolution. Important differences in the environment may cause species to stop producing chemicals that were relevant to their ancestors under different environmental pressures. Consider *Aloe vera* for example, a species renowned for its multiple health properties. It was found that its medicinal traits heavily relate to the plant's leaf succulence, which thrives in semi-arid conditions. Branches of the *Aloe* genus that evolved to lose its succulence, such as some grass aloes, show a very significant decline in medicinal properties. The loss of succulence is related to less arid conditions, where water-storing tissues are not a big selective advantage. These findings are particularly relevant to the pharmaceutical companies, which are always looking for plants with properties of interest. Knowing which features show tendencies for medicinal traits assists pharmaceutical companies in finding the next species with the winning traits to dominate the market.

Some features shared by numerous medicinal aloes include:

- ✓ Firm leaf mesophyll ("Gel" tissue inside the leaves)
- ✓ Short stem
- ✓ Ease of propagation
- ✓ Small teeth on the leaf margins
- ✓ Large succulent leaves
- ✓ Drought tolerant

Aloe vera has been found to be closely related to seven other species native to the Arabian Peninsula and the Ethiopian-Somalian region, with which it shares similar leaf properties.

Figure 2. *Aloe vera.*

The biogeographical history of aloes

From all *Aloe* species, why is *Aloe vera* the one to dominate the market, counting for an estimated annual market of $13 billion? What makes this particular species special?

To answer that question, we must go back in history to reconstruct *Aloe*'s evolution and consider the implications of the findings for the pharmaceutical companies. Data for the information described below was based on nuclear DNA evidence and two different probabilistic models for inferring the biogeographical scenario, due to the lack of fossil evidence.

Aloe is one of the world's largest succulent groups, with over 500 species. It originated around 19 million years ago in Southern Africa and suffered two major radiations promoted by speciation processes, explaining its huge diversity. The first diversification of aloes happened 16 million years ago, the late Miocene, in South Africa, spreading into the Zambezian and Ethiopian-Somalian regions around 10 Ma. The speciation processes that led to this diversification were mainly due to loss of habitat experienced in South Africa, where a rainfall regime was established benefiting drought-sensitive succulents, pushing aloes to north-eastern regions. Throughout its evolution, *Aloe* was found to have increased its succulence in several groups, becoming the only genus to show the trait in exuberance. Other species in the genus, however, lost their succulence altogether, more notably the grass aloes.

More recently, Aloes suffered another major diversification in the Pliocene around 5 million years ago, as a result of rapid fragmentation and increased niche availability, when isolated taxa dispersed short distances into the rich habitat mosaics formed by geological processes during the Pliocene. At the same time, the *Agave* family, a succulent native to the Americas, was experiencing the same diversification processes, in a curious case of convergent evolution. During this time, aloes in the Zambezian region spread to Madagascar in three dispersal events, and from the Ethiopian-Somalian region to the Congolian, Saharan-sudanian and Arabian regions in sixteen dispersal events, being a hotspot of *Aloe* dispersion. The Arabian region, where *Aloe vera* originated, was at a time the hotspot for commercial trades, being the link between Western and Eastern economies.

Ethnobotany

When considering which species have higher economic potential, it is worth taking into account the traditional medicine used by indigenous communities. When analysing species used by indigenous peoples across the globe, phylogenists found that distribution of traditionally used species is not random in regard to phylogeny. On the contrary, most species used by indigenous communities represent some clades over others. This indicates that indigenous communities independently identified the plant groups with higher presence of chemical properties for human interest. This opens a window of opportunity for researchers trying to identify clades with higher potential to be of use to pharmaceutical companies. Of course, not all is that simple. Traditional peoples depended on a relatively high dispersion of medicinal plants for them to be noticed and widely used. Identifying which plants could be used as medicine was also a lengthy process that depended on tradition and a thorough knowledge of plant morphology.

Plants of the *Aloe* genus show great use amongst traditional communities. Interestingly, 98% of aloes with reported traditional medicinal use show succulent leaves, while 87% of non-succulent aloes show no medicinal use at all. This may indicate that succulence is related to medicinal use, as found in recent research.

Activity: Considering the text above, use dashes to represent how the genus *Aloe* is spread out across continents. No aloes have been found above the line represented in the map.

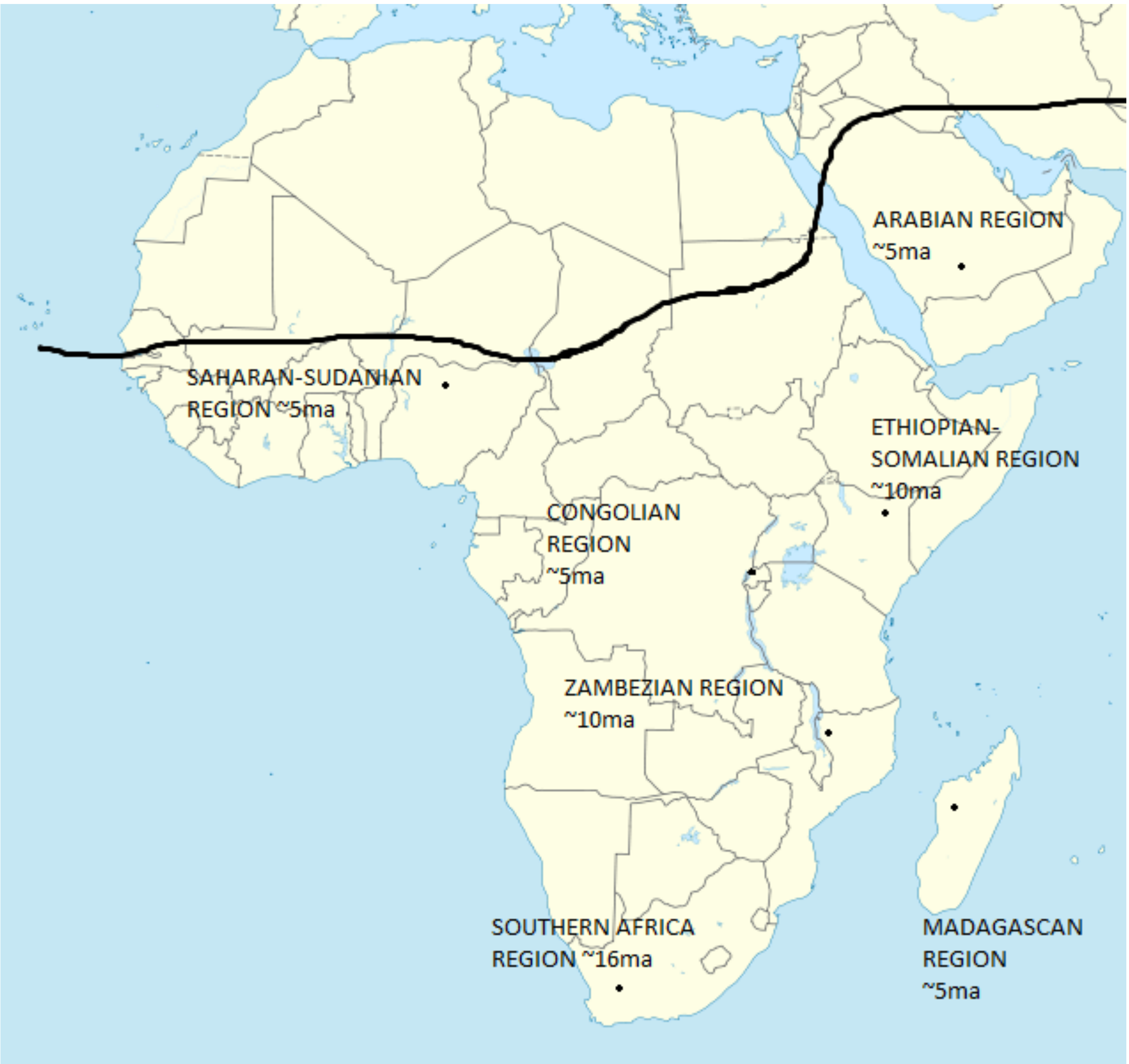


Image: Adapted from Grace *et al.*, 2015

Questions:

1. Considering that *Aloe vera* has close relatives with similar leaf properties, how would you explain its commercial success?
2. List two ways that pharmaceutical companies could find more species with medicinal properties.

3. How did the biogeographical data help in determining how *Aloe vera* came to be so successful?
4. The study done in 2015 used probabilistic models to infer the biogeographical scenario described. What could be the possible impact of finding fossils of the genus Aloe to the results of this research? How can you explain the lack of fossil evidence for that genus?
5. Consider the ongoing introduction of foreign species to a country's fauna and flora. How do you think that can impact modern studies of phylogeny?
6. Consider the underlined passage in the text and offer an alternative to the statement made.
7. Discuss the impact of human societies on the dispersion and findings of different plant species, especially considering more ancient human groups. For example, you may want to discuss how our perception of plant properties depends on our sensory systems and what we are able to perceive, and how the identification of species of interest may change their evolutionary history.

Exercise inspired by and adapted from:

Grace, O.M., Buerki, S., Symonds, M.R. et al. (2015). Evolutionary history and leaf succulence as explanations for medicinal use in aloes and the global popularity of Aloe vera, *BMC Evolutionary Biology*. Retrieved from: https://link.springer.com/article/10.1186/s12862-015-0291-7

Saslis-Lagoudakis, C. H., et al. (2015). Evolutionary Approaches to Ethnobiology. In U. P. Albuquerque, P. M. De Medeiros and A. Casas (Eds.), *Evolutionary Ethnobiology* (pp: 59-72). Cham, Springer International Publishing.

Technical review by S. M. U. P. Mawalagedera.