Ada Chen
Evolution Spring 2017
March 4, 2017
Term Project Proposal

Living Fossil Plants

My term project will focus on plant “living fossils,” plant fossils that bear striking resemblance in appearance and in DNA to extant plant species. From my research, I have learned that while “living fossils” have rightfully earned their title because they look anatomically unchanged from their distant fossilized ancestors, they are not exempt from evolutionary forces that come with earth’s shifting environments. In order to have survived these shifting environments, their physical appearances may not have needed to evolve, but natural selection would have favored physiological mutations that better suited different elemental environments. Other theories suggest that extant species have retained their physical appearances because they had developed “a winning formula early on” or their competition for resources is minimal in a predictable environment (Werth & Shear). Despite inevitable adaptive and neutral evolutionary changes at a molecular level, scientists can still use existing species of their fossilized counterparts to test theories about fossils’ living conditions and traits that have allowed them to survive relatively “unchanged” (Cafasso and Chinali; Yirka). My creative project will focus specifically on the “living fossils” of the dawn redwood, ginkgo tree, and wollemi pine— all of which flourished in the Mesozoic era as more reproductively advanced because they relied on the wind to pollinate their eggs instead of being self-pollinating like the earliest land plant, the seed fern was (Thompson 739).

The dawn redwood is particularly fascinating because of its ability to survive in a continuous light environment similar to the environment its ancestors endured. In high northern latitudes during the Eocene epoch, continuous low to moderate-intensity light would shine for up to four months straight. M. Alejandra Equiza et al conducted an experiment to discover the effects of continuous light on plants’ photosynthetic capacity using the extant *Metasequoia glyptostroboides* to represent the dominant high-altitude tree genus of this ancient environment. Their results revealed that the dawn redwood’s increased growth under continuous light decreased its photosynthetic capacity but decreased less than other coniferous species under continuous light exposure, which lead the researchers to understand how this species has surpassed others in existence. Because light was constantly available, the dawn redwood did not need to absorb as much as it did when the light was only present for hours in its current natural environment. It could photosynthesize at a lower rate throughout the day to receive the nutrition it needed as well as a surplus that produced increased growth. Though its photosynthetic capacity lowered, it was at a lesser rate than other conifer species’ capacities lowered under a continuous light environment and therefore could photosynthesize better than others if the continuous light environment began to disappear and sunlight was available for shorter amounts of time (Equiza, et al. 1458).

The ginkgo biloba species is the only living species of the Ginkgophyta division today. The ginkgo tree’s RNA contains the most editing sites of any other seed plant at 255 sites (Peng He, et al.). Since the gingko biloba exists in fossil form and in an extant form and has an abundance of RNA editing sites, Peng He and other researchers used it to study the biological and evolutionary significance of RNA editing sites. They extracted DNA from 8-week-old gingko specimens that they had grown, they identified the RNA editing sites, and they compared their results to other species' RNA editing sites. They found that many of the ginkgo's unique editing sites had disappeared in two other gymnosperms, *Pinus* and *Cycas*, suggesting that the gingko's chloroplast genome bears a closer resemblance to its ancestor's than the other two gymnosperms' to theirs. Their results also showed that most of the RNA editing sites can recover amino acid conservation and increase amino acid hydrophobicity, which are important in activating and oligomerizing protein receptors as well as in coupling proteins that detect and respond to external environments (Caltabiano, et al. 110). RNA editing physiologically benefited the gingko because it allowed it to maintain the production essential proteins through an editing process is response to its shifting environment over time.

The wollemi pine has a compelling presence because its rarity introduced many conservation efforts when three hikers accidently discovered in 1994 a small Australian grove of about two dozen *Wollemia nobilis* (McLoughlin & Vajda). Stephen Mcloughlin & Vivi Vajda elaorate in an *American Scientist* article that this species is not a true "pine" and actually belongs in the Araucariaceae family of coniferous trees in which only two other extant genera exist. The fossil record contains a relative profusion of Araucariaceae specimens that researchers have compared to the wollemi pine and consequently "filled gaps" in evolutionary theories about this coniferous family. Living, though remnant, Araucariaceae species extend from Australia to South America, reinforcing fossil evidence that this family had a once-widespread population. The survival of the wollemi pine in such small numbers constitutes it especially rare because adult plants are almost completely genetically synonymous, whereas genetically varied populations can develop mutations that help the species adapt and survive through natural selection. McLoughlin & Vajda also suggest that the Wollemia barely survived the theorized asteroid that fell onto Earth and ignited a "global firestorm" that extinguished dinosaurs and numerous other species. Though this "firestorm" subsequently created a colder, drier climate because the soot obscured the sun and fires occasionally combusted, a few Wollemia survived— as most of its family vanished— these far from ideal conditions with seeds that were buried in soil as the Earth recovered the moist and mild climates that the Wollemia prefers. As the Earth went through other phases of extreme temperatures such as all-encompassing glaciation, the Wollemia population dwindled into the naturally occurring dozens of today. The few specimens that survive today rely on symbiotic fungi to retrieve nutrients that sustain the rare group of humidity-prone plants in vastly dry Australian land.

All of these plants, though remarkably similar at first glance to their preserved ancestors, have changed and evolved in response to Earth's extreme fluctuating climates. The dawn redwood's resilience is a result of its increased ability—in comparison to other trees in identical environments— to adjust to these fluctuating climates at a photosynthetic level. Within the dawn redwood species itself, specimens that had the best ability to adjust their photosynthetic capacity endured despite the constancy of their physical appearance. The sole ginkgo tree species that exists today bears an almost unchanged resemblance to its fossilized ancestor yet is the only species to survive of its genus because its plentiful RNA editing sites gave it a superior ability to, again, adjust to vacillating environments. The wollemi pine seemed to withstand Earth's environmental fluctuations through the chance that its seeds did not dry out or freeze during severe and sudden atmospheric transitions. However, its extant species persevered because natural selection favored the specimens that persisted until favorable humid conditions returned.

The inevitability of changes that characterizes all organisms that prevailed amidst Earth's inconsistent elements and will also characterize my term project.

Concentrating on these three species of "living fossils," I want to create jewelry based on their fossils and their extant species. I will create a pair of asymmetrical earrings for each pair of species, establishing the right ear as the "fossil" ear and the left ear as the "living" ear. Earrings appear to be the best way to present the comparison of the ancient to the living because of the natural divide that the face provides between two objects and also because the symmetry of ears provides a simultaneous unity. I plan to etch the fossil imprint in copper to emulate real fossil slabs and create interpretations of the fossils' corresponding descendants to match it. The earrings of the extant species will involve more moving parts to refer to the constant motion of evolution and contrast it with the stagnancy of the etched slabs. I will represent the dawn redwood's extant leaf structure with a mobile construction so that each unit will sway separately, embodying the non-static quality of my concept. The moving element in the wollemi pine's extant leaf will materialize as leaves on tubes that are free to spin, keeping the spiraling element of the leaves on its branches. The extant ginkgo tree leaves will possess movement through the classic use of en tremblant, a method of attaching heavier element on springs or thin wire so that the elements will tremble with the wearer's motion. The kinetics in all three pieces will serve my concept as well as semi-reflect the actual undulations and vibrations of the physical leaves themselves. I will be using copper because of its susceptibility to oxidation. This change through oxidation will represent evolution's inevitable presence, even in the fossil vessel because scientists date fossils using the half-lives of the elements they have been preserved in. Half-lives of elements are anatomical evidence that all elements are vulnerable to change simply by naturally decaying. Copper is also the most malleable metal, is difficult to melt, and can endure copious amounts of fire before melting. These qualities of copper represent the malleability and endurance of all three species even through Earth's extreme "fires."

Sources

Cafasso, Donata, and Gianni Chinali. "An ancient satellite DNA has maintained repetitive units of the original structure in most species of the living fossil plant genus Zamia." *Genome*, vol. 57, no. 3, 2014, p. 125+. *Academic OneFile*, ezproxy.pratt.edu/login?url=http://go.galegroup.com/ps/i.do?p=AONE&sw=w&u=nysl_me_pml&v=2.1&it=r&id=GALE%7CA375951648&asid=869a76c56c0d55d4c6ee1a195f4bddbd. Accessed 19 Feb. 2017.

- This source is a primary source that studies that genetic variability of satellite DNA in the specific genus of Zamia, which is part of one of the oldest living groups of seed plants, Cycads. This experiment proves the heritability of genes from millions of years ago and possibly indicates similarities in environment or ability to survive diverse climates.

Caltabiano, Gianluigi, et al. "Chapter Five: The Role of Hydrophobic Amino Acids in the Structure and Function of the Rhodopsin Family of G Protein-Coupled Receptors." *Methods in Enzymology*, vol. 520. Ed. P. Michael Conn. 2013. P. 99–115. lmc.uab.cat/publications/Show_PDF.php?id=161. 26 March 2017.

- This source informed me of how amino acid conservation and their hydrophobicity function in plant development. The article about the ginkgo tree mentions amino acid conservation and hydrophobicity as essential to the tree's evolutionary development.

Equiza, M. Alejandra, et al. "Photosynthetic downregulation in the conifer Metasequoia glyptostroboides growing under continuous light: the significance of carbohydrate sinks and paleoecophysiological implications." *Canadian Journal of Botany*, vol. 84, no. 9, 2006, p. 1453+. *Academic OneFile*, ezproxy.pratt.edu/login?url=http://go.galegroup.com/ps/i.do?p=AONE&sw=w&u=nysl_me_pml&v=2.1&id=GALE%7CA156136132&it=r&asid=f22b3f41c6cb37bc6ac9345d95643b2a. Accessed 25 Feb. 2017.

- This experiment tests the effects of continuous light on the dawn redwood's photosynthetic capacity based on the assumed continuous light environment that its ancestors endured. Results revealed that the dawn redwood's increased growth under continuous light decreased its photosynthetic capacity but decreased less than other coniferous species under continuous light exposure, which lead researchers to conclude that this species' ancestors were more fit to survive.

He, Peng, et al. "Abundant RNA editing sites of chloroplast protein-coding genes in Ginkgo biloba and an evolutionary pattern analysis." *BMC Plant Biology*, vol. 16, no. 1, 2016. *Academic OneFile*, ezproxy.pratt.edu/login?url=http://go.galegroup.com/ps/i.do?p=AONE&sw=w&u=nysl_me_pml&v=2.1&id=GALE%7CA472285293&it=r&asid=87910cbd11902465c7b5895809230929. Accessed 25 Feb. 2017.

- This experiment determines the number of RNA editing sites that the Ginkgo biloba species has acquired and its evolutionary affects. Scientists draw conclusions about how these editing sights have allowed this species to earn the "living fossil" label.

McLoughlin, Stephen, and Vivi Vajda. "Ancient wollemi pines resurgent: ten years after its discovery, a vanishingly rare tree from the Cretaceous Period is a scientific darling and may soon become a commercial success too." *American Scientist*, vol. 93, no. 6, 2005, p. 540+. *Academic OneFile*, ezproxy.pratt.edu/login?url=http://go.galegroup.com/ps/i.do?p=AONE&sw=w&u=nysl_me_pml&v=2.1&id=GALE%7CA143276341&it=r&asid=e43b09813277e881e78c0ff97277276a. Accessed 26 Feb. 2017.

- This source describes the impact of the discovery of the living wollemi pine after its fossil had already been discovered and thought to have been extinct. The wollemi pine is also considered a “living fossil” because the living species looks so similar to its ancestor preserved as a fossil.

Thompson, Ida. *The Audubon Society Field Guide to North American Fossils*. New York: Knopf, 1982. Print.

- This source records North American fossils and lists their physical traits as well as their descendants next to illustrations, which in turn refer to color photographs of the actual fossils. Because this source contains imagery, it provides information that text descriptions alone would not be able to yield.

Werth, Alexander J., and William A. Shear. "The evolutionary truth about living fossils: appearances to the contrary, no species is exempt from selection, even when changes are difficult to detect in the fossil record." *American Scientist*, vol. 102, no. 6, 2014, p. 434+. *Academic OneFile*, ezproxy.pratt.edu/login?url=http://go.galegroup.com/ps/i.do?p=AONE&sw=w&u=nysl_me_pml&v=2.1&id=GALE%7CA389260650&it=r&asid=b8b7238538b1322cde7bf8e50abbf774. Accessed 25 Feb. 2017.

- This source elaborates on rightful applications of the term “living fossil” as well as its inaccuracies. This article clarifies that though extant species physically match their fossil ancestors, they are not exempt from other evolutionary changes on the molecular level.

Yirka, Bob. “180 Million-Year-Old Fossilized Fern Nearly Identical to Modern Relative.”*Phys.org*, Phys.org, 21 Mar. 2014, phys.org/news/2014-03-million-year-old-fossilized-fern-identical-modern.html. Accessed 26 Feb. 2017.

- This source is a synopsis on another “living fossil,” the royal fern, and reports on the discovery of an instantaneously preserved fern fossil, which has retained cell structure and DNA.