Ashes and Adaptations: Exploring Fire Adaptations Through a Podcast Mini-Series

Honors Thesis

Presented in Partial Fulfillment of the Requirements for the
University Honors Program
Colorado State University

By

Peyton Paa
Forest and Rangeland Stewardship

Dr. Jennifer Neuwald, Biology
Dr. Sarah Hart, Forest and Rangeland Stewardship

Fall 2025

Abstract

"Ashes and Adaptations" is a five-episode podcast mini-series discussing plant adaptations shaped by fire. The goal of the project was to create an overview of fire as an evolutionary force and explain how climate change is harmful to fire-adapted ecosystems. The audience was intended to be the general public, not just those within the scientific community. The series begins with an overview of evolution, discussing the mechanisms behind the process, how adaptations arise, and correcting the common misconceptions surrounding the topic. Then, the next three episodes dive into specific fire adaptations, including thick bark, serotiny, and the wide variety of adaptations contained within the iconic Eucalyptus tree. Finally, the series ends with a panel discussion with fire scientists Jamie Woolet and Sarah Hettema, discussing their work related to fire ecology and issues they've seen fire-adapted ecosystems facing today. With the generous help of Dr. Neuwald and Dr. Hart as advisors, this podcast was able to come into fruition. This project combined many of the skills I have fostered throughout my undergraduate experience, including research and writing, while also utilizing the knowledge I have gained from my classes in natural resources.

Keywords: Honors Thesis, Adaptations, Evolution, Fire, Ecology

Table of Contents

Section I:

Podcast Episodes pg. 4-44

the scripts from each episode of the mini-series and the recorded episodes

Section II:

Reflection Paper pg. 45-49

a brief reflection paper discussing the inspiration behind the project and the work that went into creating this podcast

December 9, 2025

Section I

Podcast Scripts

Episode 1: Overview of Evolution

[Episode 1 Spotify Link]
[Episode 1 Apple Podcasts Link]

I. Introduction

Every trait that you see in nature, such as thick bark, deep roots, or fur color, has a story behind it. This story has been written through evolution. Fire is one of the most powerful and destructive forces in nature, making any story it's involved in especially dramatic. Fire has been shaping landscapes and species for thousands of years. Understanding that story is essential for living in a world coping with climate change.

Welcome to Ashes and Adaptations. I'm your host, Peyton, and this podcast is a project I am creating for my honors thesis. I am an undergraduate student studying Natural Resources Management with minors in Conservation Biology and Ecological Restoration at Colorado State University. The goal of this podcast is to discuss the adaptations plants have developed in response to fire regimes. As the impacts of climate change become increasingly detrimental to our ecosystems, understanding fire-adapted traits is crucial for developing ecological restoration and management efforts.

For this first episode, we're going to be diving into adaptations and the misconceptions associated with them. You have probably heard of adaptations before in science class. Maybe you are picturing a chameleon's camouflage or a flower's bright colors. And you'd be right.

Adaptations are everywhere. By the end of this episode, you will understand what they are and how they arise.

If you want to dive deeper, all references and sources used in this episode can be found in the podcast description.

II. What is An Adaptation?

An adaptation is a trait that arose and was favored by natural selection for its current function. Adaptations help an organism survive and/or reproduce in its current environment. All adaptations originally come from mutations that arose, persisted, and then spread throughout a population because they provided some kind of advantage. We'll talk more about how adaptations happen later in the episode.

First, let's dive into some examples that exemplify the wide range of possible adaptations. So, what are some examples? Earlier I mentioned chameleons and their camouflage. In the short term, the proximate reason a chameleon changes color is because it has specialized skin cells that can expand or contract to alter the pigmentation of the skin, The ultimate reason for this is that chameleons who blended into their surroundings were less likely to be eaten by predators. Another example is brightly colored flowers. Take the Hibiscus flower. They're large, brightly colored flowers, often a deep red, pink or orange. The proximate reason for this is that the petals are full of pigments that create vivid colors. Ultimately, the flowers that were more attractive to pollinators were visited more frequently. Thus, they were able to reproduce more often and pass on this trait.

However, adaptations are not always physical. They can be behavioral. For example, birds migrating with the seasons or a spider spinning a web. Seasonal migration to warmer climates helps birds survive because it makes it easier to find food and shelter. Adaptations can also impact physiological timing or organism’s internal clocks. For instance, some animals, like bears, enter hibernation at specific times of the year. This helps them conserve energy when their food sources are scarce. External cues like temperature signal a bear’s internal clock to prepare for hibernation. Similarly, flowering trees time their blooming to coincide with favorable conditions for pollination by responding to environmental cues.

III. How Do Adaptations Happen?

Adaptations begin with mutations— changes in the information contained in DNA. DNA is the instruction manual for how an organism looks and behaves. Mutations are like “typos” that occur when DNA copies itself. These mutations are completely random and can be beneficial, harmful, or even have no effect at all (we call that neutral).Let’s think about what happens when mutations are beneficial to an organism. For example, maybe a mutation results in a change in the way a tree holds onto water during a drought. When a mutation is beneficial by helping it survive or have more offspring, that trait, if it is heritable, can be passed down to the next generation. Over many generations, this can shape a species to fit its environment. This process is called natural selection, and it is a driving force behind the evolution of adaptive traits. It’s nature’s way of “choosing” the traits that stick around through the generations. The traits that help an organism survive or produce more offspring are passed on to the next generation.

IV. Misconceptions

Before we continue, I want to pause and take the time to address some of the common misconceptions about adaptations. These misunderstandings are everywhere from everyday conversations to media like movies and TV shows. Let’s get into some of the biggest misconceptions.

I. The first misconception is the idea that a single organism evolves.

   a. It is a common misunderstanding that an individual organism can "evolve" during its lifetime. However, only populations can evolve. A single organism can adapt to its environment in some ways. For example, learning new behaviors like how to hide from a predator. However, evolution happens over many generations. This misconception likely stems from the casual usage of the word "adapt." People often say that an animal "adapted" to survive. This makes it sound like a conscious and purposeful change. Yet, evolution is not something an individual organism can decide to do to better their survival.

      It is important to understand that populations evolve because it helps us see that evolution is something that occurs over generations through forces like natural selection. Because of this, conservation efforts must consider the populations, not just the individual organisms.

II. The second misconception is that natural selection is forward-looking or predictive.

   a. In reality, natural selection only acts on current variation under current conditions. Evolution does not have goals or foresight into future conditions.

      For example, the peppered moth in England during the Industrial Revolution was able to survive because a mutation arose that made the organism's wings darker, matching the dark, soot covered trees. The moths did not "decide" to have darker wings in preparation for this event. The mutation randomly arose, happened to benefit those individuals, and was selected for under the current conditions.

      This misconception likely comes from the wording we use to describe evolution. Phrases like, "the species evolved to survive" often create a picture of an intentional decision. However, evolution has no direction or purpose. It is the result of certain traits becoming more common in a population because they help organisms survive in their current environment.

Understanding that evolution is reactive, not predictive helps us understand why some species struggle or go extinct when environment change too quickly for evolution to occur.

III. The next misconception is that organisms adapt because they need to.

  a. This is likely the most common misconception and it is easy to understand why. The idea of an adaptation can be confusing and understanding mutations is critical to having the full picture. I notice this the most when people say things like, "polar bears become white to blend into the snow better." The issue with this is that it frames evolution as a personal choice organisms make to better their chance of survival. This is simply untrue. Mutations arose in a population of polar bears that made their fur white. This trait likely benefited their survival because it helped them hunt prey. Then, because those bears were more likely to survive, they were more likely to reproduce and pass on their genes.

     It is also important to note that the reasoning behind scientific adaptations are purely hypotheses. Scientists can say that white fur "likely" helped polar bears hunt prey because it's a well-supported explanation. It is based on evidence that evolutionary biologists have gathered but like any good scientific hypothesis, it may change based on new evidence. For example, additional studies show that the white hair of polar bears is really translucent and may help increase their ability to stay warm in their cold arctic environment.

Understanding that evolution is not a purposeful process reminds us that it is the outcome of random variation filtered through survival and reproduction in the current environment.

IV. The last misconception we will be covering is that selection leads to perfection.

a. This is another big one. I frequently hear this one come up in everyday conversations or TV shows with phrases like, “the cactus is perfectly designed for the desert.” It’s easy to think this. After all, organisms can often seem so “perfectly” designed for their ecosystems. However, perfection is never the outcome of evolution. Natural selection acts on what is already there and selects for traits that improve survival or reproduction right now. It does not plan ahead and it does not create flawless solutions to issues organisms face.

   For example, cactus spines help reduce water loss by providing shade for the stem and breaking up wind flow to reduce evaporation, but they cannot capture sunlight like large leaves can. The cactus is “fit” for the current environment of the desert, but it is not perfect. There are often trade-offs.

   Similarly, take the giraffe for example. Their long necks allow them to reach leaves at the tops of trees. However, they also need to have a powerful heart that can pump enough blood all the way to the brain. Evolution is full of these types of compromises because adaptations benefit organisms in their current conditions. Recognizing this helps correct the misunderstanding that nature produces perfection. Even traits that seem “perfect” may have downsides. Even traits that seem “perfect” may not be if the environment changes.

So, when we are discussing adaptations, it's vital to remember that natural selection cannot predict the future or create perfection. Also, organisms do not decide to adapt to their environment. Mutations randomly arise and if they happen to benefit the organism in survival and/or reproduction, they might be passed down.

V. Fun Examples

Now that we have an understanding of what adaptations are and what they are not, lets wrap up this episode with some interesting case studies on adaptations.

The Antarctic Icefish lives in water so cold that it would freeze your blood. Yet, these fish have their own natural antifreeze. Their "antifreeze proteins" are molecular adaptations that prevent ice crystals from forming in their blood. A study published in 2009 by Kevin Bilyk and colleagues from University of Illinois at Urbana-Champaign explored this ability in 11 species of Antarctic icefish. By measuring the serum hysteresis freezing points (a measure of how much the blood serum resists freezing), they found that species found at higher latitudes had lower serum hysteresis freezing points, meaning they are better at resisting freezing.

Next, imagine walking through the rainforest and suddenly thinking that you have stumbled upon a decaying carcass, only to discover a giant flower. The *Titan arum*, or "corpse flower," has one of the most powerful and foul smells in the plant kingdom. It rarely blooms, but when it does, it releases a strong odor that many describe as rotting flesh. This odor attracts pollinators that usually feed on dead animals.

Recent research by Vijayasankar Raman and colleagues at the University of Mississippi in 2025 analyzed the chemical profiles of the odors emitted throughout the blooming process. They found that the closer the emitted odor profile was to decomposing flesh, the more likely the insects were to pollinate the plant. Also, the plant's chemical signature changed over the blooming stages, with the scent profile matching that of a decomposing corpse the most when the flower is most receptive to pollinators.

VI. Conclusion

That wraps up our first episode of Ashes and Adaptations. Today, we discussed adaptations, how they arise through random mutations and are selected for through natural selection, and common misconceptions surrounding them. Remember, adaptations do not lead to perfection, and they are not a conscious choice.

We also dove into some interesting examples of adaptations, from Antarctic icefish resisting freezing in sub-zero water using their own natural anti-freeze to the corpse flower using a similar scent profile to a decaying carcass to attract pollinators. These examples show how diverse and surprising adaptations can be.

Next time, we will be diving deeper into specific adaptations that benefit plants in their fire regimes. Fire has shaped ecosystems as an evolutionary force for millions of years and there are many interesting adaptations that plants have developed that help them survive or even depend on it. From seeds that open up to germinate after a burn to thick bark that acts as a shield against heat, fire-adapted traits are everywhere.

This first episode allowed us to lay the foundation by discussing what adaptations are, how they arise, and correcting common misconceptions about them. This will be helpful going into the following episodes of this series because we will build off of these ideas with each fire-adapted trait.

Until next time, thank you for listening! Please join us in the next episode, where we will be diving into our first adaptation: thick bark!

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Episode 2: Layers of Survival

Episode 2 Spotify Link
Episode 2 Apple Podcasts Link

I. Introduction

Wildfires can reach temperatures hot enough to melt aluminum, so how does a living organism survive that level of heat? For some trees, this answer lies in a deceptively simple trait: a layer of thick, protective bark. In this episode, we'll dive into how a simple feature like thick bark can be one of the most fascinating fire adaptations on Earth and why it matters now more than ever.

Welcome back to Ashes and Adaptations. I'm your host, Peyton, and today we're going to be discussing a deceptively unassuming, but powerful trait: thick bark.

When we think of adaptations, we often imagine more exciting or dramatic traits, such as snake venom or a corpse flower's pungent smell. But sometimes, adaptations that outwardly seem less flashy, are critical for an organism's survival. Imagine an armadillo's built-in armor. It may have a dull gray appearance and seemingly awkward weight to bear, but this trait helps the mild-manored armadillo protect itself against the claws of a predator like the jaguar. Similarly, you may not consider the thick bark of a tree as being an important adaptation for tree survival, but it endures and protects the individual from harm, such as the heat of a fire.

Thick bark allows trees to survive in ecosystems with frequent fires. This adaptation is extremely common, appearing in ecosystems all over the world. In today's episode we will specifically discuss how fire shapes ecosystems, the science behind bark thickness, variations among species, and limitations regarding thick bark as an adaptation.

If you want to dive deeper into this subject the citations will be included in the description.

II. Fire as an Evolutionary Force

To understand why adaptations like thick bark matter, we first must explain how fire can act as an evolutionary force. Fire-adapted ecosystems are defined by their "fire regime." A fire regime characterizes the historical pattern of frequency, seasonality, intensity, and severity of fires in the area over time. One of the key components of a fire regime is the "fire return interval." This is the average time between fires in a given area. Ecosystems such as savannas, longleaf pine forests, and ponderosa pine forests are described as having a frequent-fire regime. These ecosystems deal with high frequency, low severity fires enough to consider "fire" a component of the ecosystem. In these ecosystems, fire is a necessary process that clears the understory and recycles nutrients. Thick bark is one of the most common adaptations trees use to survive frequent surface fires. Now, let's investigate why that is.

III. The Science of Thick Bark

So, how does thick bark protect a tree? Tree bark is made up of the outer bark, or the periderm, the inner bark, or the phloem, and the cambium. Bark protects the vital tissues, such as the cambium and the phloem, from damage. During a fire, these tissues are extremely vulnerable to heat damage. If the cambium and phloem are damaged in a fire, the tree can no longer transport nutrients or grow, often causing it to die. Think of this like electrical wiring inside of a house and the bark is the house's insulation. The cambium and phloem keep everything running behind the walls, but they can be damaged by flames. If a fire burns through the "wires," the lights may stay on for a moment, but they will eventually shut down. This is like a tree that cannot transport nutrients through its phloem anymore. While the tree may be able to survive for a time, it will eventually die from starvation.

Trees with thick bark can insulate these structures from heat damage during fires. It slows the heat transfer to the cambium by increasing the distance the heat must travel to reach the living tissues. This means that low intensity fires have more difficulty reaching lethal temperatures that can get through the thick bark. A 2023 study done by Javier Madrigal and his colleagues at the University of Madrid demonstrated that trees with thicker bark tend to have shorter durations of harmful temperature exposure in the cambium, improving their likelihood of survival.

Some classic examples of species that exhibit this trait are ponderosa pine or longleaf pine. Their bark can be several centimeters thick even as young adults.

IV. Variation

It’s important to note that bark thickness can be incredibly variable both across species and even within a single tree. Some species have thick bark mainly at the base, protecting them from surface fires that mostly impact the trunk. Others have thick bark that extends along their branches, allowing them to survive taller flames. A 2016 study done by Julieta Rosell at the University of Mexico found that species in ecosystems impacted by frequent tall grass-fueled fires that impacted the crowns were more likely to have thick bark on their stems and branches.

Even within a species, bark thickness can vary among individuals and with age. Trees often develop thick bark as they age. For example, ponderosa pine trees typically only develop thick bark after six years. This genetic and developmental variation among individuals is what allows natural selection to occur. The trees without thick bark are less likely to survive a fire and pass on their genes.

In ecosystems with less frequent fires, trees tend to have thinner bark. These species often rely on other strategies to survive instead. But why wouldn’t thicker bark be favored in these systems? Let’s consider some limitations of having thick bark.

V. Limitations

Unfortunately, thick bark is not a cure-all. There are trade-off and limitations. Trees use energy to invest in thicker bark, which can slow growth and reduce other defenses. Also, as we have discussed, thick bark is far less effective in fire regimes characterized by high-intensity crown fires. These flames have high enough temperatures to engulf an entire tree and render the thick bark useless in protecting the inner tissues. This brings us to the modern challenge associated with this adaptation.

Today, many ecosystems are dealing with the consequences caused by decades of fire suppression. Allowing fuel to accumulate can lead to fires that are more severe than the historical fire regime. On top of that, climate change only makes these conditions worse. A study done by Calum Cunningham and colleagues at the University of Tasmania found that from 2003 to 2023, the frequency of extreme wildfires increased 2.2-fold and their intensity by about 2.3-fold. Think of this like a neighborhood that used to experience a small kitchen fire once every couple of decades. Today, the neighborhood experiences fires that engulf an entire house every decade. That's how serious a 2-fold increase in wildfire frequency and intensity is for an ecosystem. These trees that evolved under frequent surface fires may now face more severe crown fires that they are unable to survive.

VI. Conclusion

Thick bark is an unassuming but powerful adaptation that has helped trees survive and thrive in their historical fire regime for millennia. Understanding how it evolves and why it benefits species allows us to further appreciate the resilience of fire-adapted ecosystems. For natural resource managers, this knowledge is critical for making informed decisions about prescribed burning and conservation priorities. So, while evolution is not forward-thinking, we can be! Managers can use the evidence from studies such as the ones described here to anticipate how forests may respond to future environmental changes and create strategies that support resilience, biodiversity, and reduce risk.

With climate change altering fire regimes in ecosystems all over the world, species that are well adapted to their historical fire regimes are being tested beyond their limits. Populations can only adapt using the genetic variation they already have. Because of this, not all species will be able to keep pace with the rapid environmental changes occurring.

Thank you for joining me on this episode of Ashes and Adaptations. If you enjoyed today's discussion, be sure to check out the sources in the description. Please join me next time when we explore another fire-adapted strategy in plants: serotiny!

Episode 2 Sources:

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Episode 3: The Waiting Game

Episode 3 Spotify Link
Episode 3 Apple Podcasts Link

I. Introduction

Welcome back to Ashes and Adaptations. I'm Peyton, and today, we're discussing one of my favorite survival strategies in the plant world.

Picture a massive wildfire moving through a forest. Afterwards, the area is black, covered in ashes and smoke. It may seem like a wasteland. However, if you pay close attention, you might see seeds falling through the leftover haze. These seeds have been released from cones that were waiting for this very moment. It’s called serotiny. For some trees, fire is a signal to begin again.

Today, we are going to be exploring the science, the strategy, and strange beauty behind serotiny. As always, if you want to dive deeper into this subject, the citations will be included in the podcast description.

II. What is Serotiny?

Serotiny is a reproductive strategy where a plant releases its seeds due to an environmental trigger. Usually, this trigger is heat from a fire, but it can also be other triggers, such as chemicals or drought.

Serotinous plants wait for the perfect moment to release their seeds, when the competition has been cleared, and the nutrients are abundant. Instead of dropping seeds every year and hoping they germinate and survive, serotinous plants hold onto theirs until the landscape is ready to support them.

This is an especially common strategy in fire-prone ecosystems, such as lodgepole pine and jack pine. It’s also a great example of convergent evolution, species in different areas, evolving the same trait independently from one another.

Overall, you can think of serotiny as playing the long game and waiting for the right moment.

III. How Does it Work?

So, how does it actually work?

For this, let’s take lodgepole pine as an example. If you have ever looked at a lodgepole pinecone, you might notice something unusual. The scales are sealed shut with a sticky resin. This resin is the key behind serotiny. It helps keep the cone tightly closed until the environmental trigger occurs.

When a wildfire occurs, its intense heat softens and melts the waxy resin, causing the scales to pop open. Then, the seeds can fall onto the nutrient-rich ash bed left behind. Think of this like a candle. Once a candle has been lit, the heat softens the wax and allows for the scent inside to be released. In the same way, fire softens the resin sealing the cones, allowing for the seeds to spill out and fall onto the forest floor. And this doesn’t take long. Sometimes cones can open within minutes of exposure to high heat.

Next time you’re walking through a burned forest, take a moment to look at the ground. You may see a carpet of small seedlings, beginning the next generation. The post-fire blackened soil creates dream conditions for a seed. There is no shade, no competition, and plenty of nutrients leftover from the burned plant material.

And here’s something fascinating: not every lodgepole has the same degree of serotiny. Studies by Tania Schoennagel and colleagues at the University of Colorado have shown that there can be degrees of serotiny that vary among populations withing the same species based on an area’s fire frequency. For example, lodgepole pines in Western North America with frequent, severe fires tend to have more serotinous cones. However, lodgepole pine in regions with less frequent fires tend to have lower percentages of serotinous cones.

In other words, serotiny isn't an "all or nothing" type of strategy. Some forests might have nearly every cone sealed shut, while others contain a mixture.

IV. How is This Beneficial?

Serotiny raises some interesting questions when we start to dissect it from an evolutionary perspective. The main question is: why would a plant ever evolve to delay reproduction? This seems like a risky move that could really backfire. The answer lies in the idea of risk versus reward, and the reward is enormous.

In ecosystems with frequent fires, seeds dropped pre-burn face issues such as dense shade, heavy competition, cold soil, and predation from herbivores. However, holding onto seeds until after a fire increases the survival odds by eliminating most of those challenges. The biggest threats of competition, shade, and cold soil are nearly gone. So, even though serotiny delays reproduction, the reward is survival and success.

Also, this trait is heritable. In order for an adaptation to be able to be passed onto future generations it must be heritable. A 2012 study out of the University of Nevada, Reno by Thomas Parchman and colleagues revealed clear genetic variation in the degree of cone serotiny in lodgepole pine. This means that natural selection can act on the trait and shape this adaptation based on the fire-regime of the environment in which a population lives.

V. The Role of Serotiny in an Ecosystem

Post-fire, species with serotinous cones are often the first to recolonize the burned area. They create structure, shade, and habitat long before other species return to the area. Their seeds land in the nutrient-rich soil and germinate quickly.

Wildlife often depends on these species after a fire. Species such as red squirrels use the serotinous cones for food while other species, such as black-backed woodpeckers, use the young trees for nesting habitat. Thus, this regeneration cycle increases the overall biodiversity of the region. Without these pioneer trees, many species would struggle to survive after a major burn.

However, this cycle is being tested by climate change. As fires become more severe and more frequent, some regions are experiencing what is called “interval squeeze.” This occurs when fires occur too frequently for younger trees to reach cone-bearing age. Then, when fires occur, these species are unable to regenerate using their serotinous cones because most of their population is too young to produce cones.

On the other hand, fire suppression has caused trees to age past their serotinous phase. Then, when fire does occur, the seed availability is too low to regenerate an entire stand. This balance that serotinous species rely on is shifting and that is cause for concern for the future of these organisms – and the entire ecosystem. Either of these extremes can break a system that has evolved around timing and balance.

Forest managers are now trying to balance prescribed burns with regions’ natural fires to preserve serotinous species. But, as climate conditions change faster than forests can adapt, this becomes increasingly difficult.

VI. Beyond Pines

While I have been mainly focusing on pine species, serotiny is not exclusive to conifers. For example, Banksia species in the Australian bush have woody follicles that will burst open after being exposed to heat or smoke. Some species do not need flames. Chemical compounds in smoke can promote seed germination by breaking dormancy and signaling that a fire has passed.

In Mediterranean ecosystems, shrubs such as Cistus, or the rockrose, show serotinous behavior as they delay the release of their seeds until after a fire.

Lastly, Hakea species exhibit a variation deemed “weak serotiny.” This means they hold onto their seeds until the plant itself dies, guaranteeing reproduction at the end of life.

These examples show that serotiny has evolved across continents and that fire is frequently a force that shapes flora and ecosystems.

VII. Conclusion

So, next time you walk through a forest and find a cone glistening with hardened resin, you can remember the potential it holds. That small structure represents patience and renewal through fire.

From the ashes and destruction of fire, serotiny shows us that nature can persist.

Thank you for listening to Ashes and Adaptations. As always, you can find the references and further reading in the episode description, including papers from Parchman and Schoennagel, on serotiny. Make sure to tune into our next episode where we will be discussing the Eucalyptus tree and its surprising list of fire-adapted strategies.

Episode 3 Sources:

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Episode 4: The Phoenix Tree

Episode 4 Spotify Link
Episode 4 Apple Podcasts Link

I. Introduction

Imagine standing in a forest, in the same spot, for a million years. You watch as species evolve and go extinct as the climate swings. Throughout this, you notice one force that returns over and over: fire. To some organisms, fire is a catastrophe. However, as time goes on, you notice that some of the plants have developed strategies to coexist with fire. This becomes a predictable rhythm that sculpts the ecosystem around you. Fire starts, sweeps through, and then, life returns.

Welcome back to Ashes and Adaptations. I'm your host, Peyton. In our previous episodes, we've discussed how fire shapes species as an evolutionary force. Specifically, we've explored two adaptations plants use to survive fire: thick bark and serotiny. Today we are diving into how plants regenerate after a fire. We'll be answering the question: how do plants come back from this disturbance? Also, what can these adaptations teach us about resilience and management strategies in the face of climate change?

II. Various Examples

Plants across the globe have evolved fascinating strategies for regenerating after a fire. For example, shrubs such as manzanita and chamise resprout after intense burns with the help of lignotubers. A lignotuber is a woody swelling at the base of the plant that contains dormant buds and nutrients. Think of this like the tree's savings account or an emergency stash of resources. Even if a severe fire destroys the tree's above ground growth, the tree can withdraw its stored energy from the lignotuber and sprout new stems post-burn. These shrubs don’t just survive the fire. Many actually grow back thicker and more vigorously after a fire, utilizing the empty space before other plants can return.

Australia offers even more dramatic examples of post-fire regeneration strategies. Some Acacia species actually germinate more effectively after being exposed to chemicals in smoke, particularly butanolides and nitriles. These chemicals can break seed dormancy and promote germination.

Even grasses have evolved an interesting strategy. They can regrow rapidly after a fire due to extensive underground rhizome networks. Rhizomes are horizontal underground stems. Because they’re underground, they can help plants survive by protecting buds and growing points from the heat aboveground. Then, after a fire, the plant can resprout from the growing points on the modified stems.

All of these examples show the unique ways that plants have evolved to live with fire. Among the world’s fire-adapted plants, one genus stands out. Now, let’s dive into the main event of today’s episode: the eucalyptus tree. Its various strategies allow it to survive and even thrive after fires.

III. Epicormic Budding in Eucalyptus

Eucalyptus trees are an iconic species in Australia, thriving in diverse environments from coastal areas to temperate forests and covering millions of hectares across the continent. For millions of years, Australian ecosystems have experienced frequent, severe fires. Eucalyptus uses fire not just as an obstacle to endure, but as a tool to strengthen its dominance in the ecosystem.

Eucalyptus trees have a remarkable adaptation that allows them to rise from the ashes of a wildfire. Epicormic budding is an adaptation where dormant buds lie beneath the tree's bark along the branches. When a fire sweeps through the region, the heat, light, and hormonal signals awaken these buds. Within days of the disturbance, these buds explode from the ash covered branches. This trait has inspired botanists to refer to the eucalyptus as the "phoenix tree." A study done in 2017 by Juli Pausas, Jon Keeley, and their colleagues at the University of Valencia found that epicormic resprouters are the most resilient trees to high-intensity crown fires. However, this is just one layer of insurance eucalyptus trees employ. They also contain lignotubers, the savings account we discussed previously, and serotinous seeds.

We explored serotiny in episode three of this series, but let's do a refresher. Serotiny is the release of seeds from a capsule caused by an environmental trigger, such as heat from flames. Fire creates ideal conditions for new seedlings by reducing competition and creating nutrient-rich soil. In essence, fire clears the stage for eucalyptus plants to begin their next generation.

Eucalyptus also have an incredibly ironic adaptation: flammability. You wouldn't think that this could be a beneficial trait, but for this species it is. Eucalyptus leaves are covered in volatile oils. These oils help the tree deter herbivores and insects, but when a fire arrives, they become fuel. They cause the entire tree to burn hotter and spread faster. A study done in 2024 by Nicolas Younes from the Australian National University and his colleagues found that oil content, water content, and leaf area also were main drivers in the flammability of eucalyptus. Flammability, in this sense, is not a weakness, but a tool. This helps ensure that the post-fire conditions will favor eucalyptus regeneration by shaping the environment in favor of themselves. It reduces competition by clearing out the nearby vegetation and therefore promotes seedling establishment by creating bare ground for the new seeds to germinate in.

These adaptations work together to help the eucalyptus tree survive and endure wildfires of various intensities. However, this is becoming increasingly difficult in recent years.

IV. Modern Challenges

Because populations can only evolve based on their current conditions, even the eucalyptus is having trouble dealing with the modern impact of climate change. These trees do not have adaptations that can protect them from the serious intensity and frequency of fires in recent years. During the 2019 to 2020 bushfire season, Australia experienced the infamous Black Summer fires that burned over 46 million acres. A study done in 2021 by Rachael Nolan from the University of Cincinnati and her colleagues argued that the rate of change in fire risk, caused by climate change, is moving too quickly for ecological systems to adapt. These fires were associated with record-breaking fuel dryness and the hottest year on record for Australia, creating the perfect storm. Both lignotubers and epicormic buds faced stress from repeated severe burns, reducing their resprouting effectiveness. This is a prime example of how climate change is disrupting the rhythm and cycles of these ecosystems, mismatching the adaptations with the new reality these species face.

V. Conclusion

The story of the eucalyptus tree is one of resilience and using disturbance as an opportunity to get ahead of their competition. Humans can learn from this approach as well. Working with fire and seeing it as an integral part of the ecosystem, rather than suppressing it has become a more popular goal in natural resources management in recent years. However, this idea is not new. Indigenous cultural burning has taken place for tens of thousands of years in places like Australia. It has demonstrated the benefits of frequent, low-intensity fires in reducing catastrophic wildfires down the line. Understanding these adaptations is just another step in the process of working with fire, rather than against it.

Make sure to tune in next week for a very special final episode. We'll be meeting with two ecologists, Jamie Woolet and Sarah Hettema, to discuss their work and opinions on the current issues in fire ecology. Until then, thank you for listening!

Episode 4 Sources:

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Episode 5: From Soil to Canopy

Episode 5 Spotify Link
Episode 5 Apple Podcasts Link

Peyton: Welcome back to Ashes and Adaptations. I'm your host, Peyton. And today, we are wrapping up this mini-series with two guests whose work spans from soil to canopy, Jamie

Woolet and Sarah Hettema. All right, to get us started, could you both introduce yourselves and share a bit about your work? Sarah, you could start us off.

Sarah: Yeah, hi, my name is Sarah Hettema, and I finished my master's at CSU this past May, but I continue on to be a spatial analyst, and I work with Camille Stevens-Rumann and some folks at the Forest Service, and I broadly study wildfire treatment outcomes, and my master's work led me very well into the position I'm in today. It's still the same project. I'm just looking at more of the Western US and working with more people. But my master's focused on the Front Range, which was a bit of a broad definition of the Front Range. So, it's Southern Wyoming to Northern New Mexico and everything east of the Continental Divide. So really that location where there's a lot of people in Colorado interacting with forested ecosystems that are adapted to fire.

Peyton: Jamie, do you want to go?

Jamie: Sure. So, I am a PhD candidate, also studying with Dr. Camille Stevens-Rumann. I'm expecting to graduate next year. So, my work in fire ecology has kind of spanned across different taxa and like different regions. So, I started off looking in soil microbial communities in the boreal forest following wildfire. This was before grad school. And then my master's work led me to the western forests, where I looked at bird communities and how they responded to fire, both like right after a fire, so one year post fire and around 25 years after a wildfire. But my work during my master's led me to really appreciate pinyon-juniper wildlands. And I've become very engrossed in the system, especially since we're not seeing a lot of recovery after wildfire. Even 30 years, we're not seeing many seedlings at all. And so, my recent work is looking at the biotic and abiotic interactions and how that influences recovery trajectories in pinyon-juniper wildlands.

Peyton: Awesome. Thank you. And then, do you guys want to share how you first got interested in fire ecology or just wildfire in general? Was there maybe a specific moment or a class or an experience that really pulled you into this field?

Sarah: Yeah, I think my interest in fire ecology really came from my undergraduate experience. I grew up in California and I did my undergrad in California. And fire is obviously a really big part of that landscape. And so, in some of my coursework, at the same time, in my coursework, we were talking about fire adaptations and a lot of it was about indigenous fire stewardship and the use of fire as an ecosystem service. And while that was happening, there was also the first time in my memory that the wildfire crisis was really impacting like a big urban area. And so, the air quality was really poor. And so, I think those kinds of things really heightened my interest in those things. And I always knew I wanted to do something related to the environment and maybe something with climate change. And fire just kind of really pulled me in. And then I was able to kind of continue to pursue that interest. And I did it in more of a technical way in some ways. Like most of my work is geospatial. And so, I have honed a lot of GIS skills and like data science skills through my undergrad and then pursued that after I graduated. But whenever I had the opportunity to like focus on a specific project, my interest in fire was what held strong. And the department that I was in was really similar to CSU's department of or the College of Natural Resources. And so, I was able to be around people who studied Western forests and fire ecology and got to take some of that coursework. So, I think it was a spark that I continued to kind of keep going back to. But I don't know if I have a specific memory. It would be awesome if I did, like a specific moment. Yeah, Jamie, what's your answer?

Jamie: Yeah, so for me, it's more something that I just fell into. Like I'm from Indiana and we don't really have wildfires there. But during my undergraduate, I worked as a lab assistant in a soil microbiology lab. And then after I graduated from undergrad, that research experience led me to be able to take a job as a lab manager in another soils lab. And that's the soil lab that looked at post-fire microbes. And so besides being on a few small, prescribed burns for ecology class, or we had a research project that looked at soil microbial communities after a prescribed burn in jack pine forests, besides those two, I had a very, very, very minimal experience with wildfire. That was until about 2019, where we were doing fieldwork in Canada, in the Northwest Territories and in Northern Alberta. And this was right when the fire season started in Canada. And this was also like a couple years after there was a lot of acreages burned in the boreal forest. And so, when we were doing fieldwork, we had to go drive up and maneuver, detour around cities that had been evacuated, which was insane to be exposed to. And then some of our field sites, we had to be helicopter dropped into because they were so remote. And so being in a helicopter and flying over these massive, burned areas was...That's what got me into fire ecology. It was that experience because before that, it was just like, oh yeah, these are soils from a burned area, whatever. I needed that contextualization to be like, these landscapes are totally different. And it was also that experience that I was like, I want to know more, and which led me to want to go to grad school and study fire ecology, but more on the tree side of things, because seeing how massive these fires are, and even though burns are often heterogeneous, there are still these really, really high severity patches that are just so far removed from any live tree, that it's like, how is anything supposed to come back in this, like in this spot that we're flying over right now, like how is a tree going to get here? Yeah, that's how I got into this.

Peyton: That's awesome. Thank you, guys, for sharing. I always think it's so interesting just hearing how people got into their fields, and whether it was like a winding journey, or if it was just a specific moment, it's always so interesting to hear that. But I want to start by grounding our listeners a bit. So, when we specifically discuss fire adaptations, what does that mean to you guys in the systems that you specifically work with? And Sarah, we can start with you again.

Sarah: Yeah, I think maybe to add additional context to my specific research, I look at landscape-level fire and fire treatment interactions, or just like what is fire doing at a really big scale. And so, it's mostly at the fire level. And some of those fires are relatively small, but there's still hundreds of acres, really large amounts of area being burned. And so, to do this, we use a lot of spatial data. So that includes things like satellite data, or things like a polygon that represents some sort of treated area. And so, because we're looking from space, essentially down to the ground, I'm not really looking at individual species and how those species are adapted to fire. So, I think when I think a lot about specific adaptations, I'm thinking more of like, how is an ecosystem generally adapted to fire? And so, thinking more along the lines of like fire regimes. And so, for our listeners, that includes things like what time of year did the fire burn? How frequently are fires expected? Or how frequently were they historically burning through a specific area? It's called the fire return interval. Or like how intensely is that fire burning? And so, a lot of my research looks more like forest type in particular. So, a ponderosa pine forest is going to have a very different fire regime than something like a spruce fir forest. And so, I'm thinking, yes, I'm thinking about specific adaptations because those dominant tree species are really influencing what's in the general ecosystem. But because of these satellite limitations, I'm really only able to look at what is happening from the canopy level. And so, we're really only able to pick up trees and how trees are either surviving or not. And there's other ways to get at different things. But my very specific thing is kind of more on that like fire regime level. So, I think that's kind of where I think about fire adaptations in my work. And I think Jamie's answer will probably be very different than mine. So, I think it will be interesting to do Jamie's side of things.

Jamie: Yeah. So yeah, I'm more on the ground side, which is like it's awesome to have like these two different viewpoints. So, fire adaptations, like in general, we think of them as traits that allow for a species to persist under, like either survive or persist under a certain fire regime, which also, thank you, Sarah, for defining fire regime, so I don't have to. And so, this is really interesting for me, because since I study and spend a lot of time in Pinyon-Juniper Woodlands, they have a very different relationship to fire than what we typically see in the West. So, for a quick background, Pinyon-Juniper Woodlands are like, they span across the southwestern U.S. in Colorado, New Mexico, Arizona, Utah. There's like different species in Nevada, some in Idaho. And so it's a very, very widespread ecosystem type. And the trees, both *Pinus edulis* in Colorado and Juniper, so *Juniperus monosperma*, they actually have very, very few of the classical fire adaptation traits that we see. So even though they live in a fire-prone system or a fire-prone region, so both Pinyon and Juniper, they have thin bark, they are highly flammable, they're short in stature, and they have low branches. And so, they don't have physical traits that allow them to survive a fire. But also, they don't have serotinous cones, so cones that opened up when exposed to heat. They don't hold a canopy seed bank, and they don't re-sprout. So basically, if a fire moves through these areas, the trees and their potential successors, their potential offspring or the seeds, they're completely lost. Not to mention also that pinyon have very, very heavy seeds that need to be dispersed by some kind of vector, either a bird or a rodent. Also, their seeds are only viable for a year, so they don't just stay in the system and can be moved later on, a few years later. They have a very, very small window where recovery is even possible. And so, all of that combined makes a system really, really interesting to study after a fire because they lack those things that we see aiding in the recovery of other forests in the West. It ends up being a big mystery, which can be a little fun or a headache.

Peyton: Now specifically, I want to start with, so Sarah, you've worked with the Colorado Front Range and analyzing more landscape level wildfire treatment outcomes. So, I'm curious if you are seeing signs that our vegetation communities are no longer adapted to the fire frequency and intensity that we're seeing today.

Sarah: Yeah, so Colorado is a really interesting place to study fire because we have such an incredible elevation gradient. And the Colorado Forest Restoration Institute has a really great infographic that shows how fire regimes change over this elevation gradient. And Jamie was just getting into the very specific species adaptations, or lack thereof, in “PJ” or Pinyon-Juniper Woodlands. There are a lot of adaptations that we see across these different elevations. And so, my work, I specifically looked at forest type because that is a unique challenge or unique aspect of the system that I was studying. So, we have a range of elevation. And so, starting at lower elevations, which it's funny to say lower elevations because I'm talking about like, you know, 5,000 feet elevation is low, which is not low in other states or even, yeah, just definitely we're talking about a very specific ecosystem. But that is we've seen in the literature and what I found in my research is that a lot of these ponderosa pine forests that are adapted to frequent fire that is at a lower severity are when a treatment and a fire interact. If that treatment included something like a previous wildfire or a prescribed burn that we're seeing that there's really positive outcomes and that those treatments are ending up with lower burn severity, which is the way that we are kind of looking at broadly ecosystem function or just ecosystem health after a fire. And so that's normal and expected. And that's not to say that there aren't threats and pressures and we're seeing in some of those systems when there's really high severity or really extreme weather conditions that those ecosystems are suffering as well. But generally, I would say that our lower forest types like ponderosa pine or mixed conifer, those are more or less kind of doing okay. Where I really see the concern, and I just recently went to another person, a talk that was talking about bees. And so, a little outside of our wheelhouse, but they're talking about the major threat is a lack of information. And I think that is really where our high elevation forests are threatened, is that we don't really know a lot about what management in those systems looks like. Because we're seeing, or historically, these systems, the numbers range, but really, like we're seeing 100 plus year fire return interval. And so, we've seen about a hundred years of fire suppression policy, even longer of interruptions to historic fire regimes. And with that, we're seeing a lot of like infilling and in kind of these like homogenized forest structures in high elevations, which leads this issue to where, if you think about some of the really large fires that have impacted the Colorado Front Range, like the Cameron Peak Fire, which happened in 2020, or the East Troublesome Fire, those are just two of Colorado's largest wildfires. They both started or really heavily impacted high elevation forests. And so, Jamie mentioned this a little bit, but the concern about kind of like going to Canada and seeing these really, really large patches of high severity, that's really where I think the concern lies. And in some of these systems, so like spruce-fir, for example, has some fire adaptations, but really their regeneration takes a really long time. And so if a really large patch of spruce-fir is burned, historically, it would have maybe a hundred years to recover before the next time a fire burned through that area. And now that window is getting shorter. So that's a really big threat to those systems. And so, for something like lodgepole pine, which does have serotinous cones, which Jamie mentioned, so that's essentially those cones require fire to open. And instead of having a trait like ponderosa pine where they want the tree to survive for the low-intensity fire, this system is adapted for high severity, stand-replacing fire, but has cones that are able to open up post-fire and regenerate a new stand, just a younger stand. But again, if it doesn't have enough time to regenerate after fire, it still takes a while for those trees to get to an age in which they're able to produce cones or able to produce a cone crop that would allow that forest to regenerate in the same way that we see it today. And so, I think where I really think about the pressures or like what we're seeing in terms of fire suppression and threats to these systems is that these high elevation forests are there. We have seen that their frequency of fire has increased over the past 2000 years. And then something like the 2020 fire season, these areas which we call like late snow zone areas, they burned more in 2020 than the previous 36 years combined. So that's a big threat to them. And they're also warming at higher rates than other systems. So, I think all of those threats and the just system being adapted to these long fire return intervals, that's shifting pretty rapidly. And just our lack of knowledge of like how we protect them and how do we manage these systems is I think a pretty big, big threat that I see in my research. And yeah, we're seeing really high severity patches being impacted in that our current methods of treatment are really not showing much improvement. So, we need to do a lot to learn more.

Peyton: Now I want to turn it back to Jamie. I know more recently, you've been working with pinyon-juniper, but in your 2023 study, you highlighted the dominance of fast-growing bacteria within the first few years after a fire. So why do you think that a more fast response is a successful adaptation after a fire?

Jamie: Yeah, I find the microbe portion of post-fire recover really interesting, just because there's like, in a lot of ways, we can relate what we typically see above ground with plants to what's also happening below ground. And so, on the plant side of things, after a fire, we see an influx of early colonizers that grow really fast. And so that's the same thing happening below the ground. And so basically, we see this influx of fast-growing bacteria because they have the ability to utilize that pulse of resources that a wildfire opens up. And so, after a fire, we have this like brief amount of time where there's a bunch of nutrients that are input into the soil. There's a ton of space that opens up because the fire had killed a lot of the other bacteria that was living there. And so, and because of that, there's also low competition, like with what we see in plant communities. And so, the organisms that are able to get there first and reproduce quickly and utilize those resources are going to be the ones that can establish themselves. In that same study, we found that those fast responders were highly prevalent, like one to two years after the fire but we saw that effect go away kind of five years. And that's also aligns with what we see in, that was an incubation study, but it also aligns with what we're seeing in the natural community. So, after about five years, after a wildfire, we often see the community of bacteria kind of like reestablish themselves. So, if we think of all of that in terms of ecological succession, it's those early colonizers that are acting as a way to change the environment to eventually make it suitable for other species. And then eventually, the more slow growing and like bacteria that have, that might, maybe they have better like competitive abilities, they're able to dominate and take over as the resources start to become more limited.

Peyton: And then with climate change, do you have any concerns with that, with the changes in fire return intervals and frequency and intensity of fires impacting overall soil health?

Jamie: Yeah, so in a lot of ways, there's not like a ton of research that looks into that. I have another study that looked at how short fire return intervals affected the bacterial communities, and we didn't see like a big effect. But if we think of, so often bacterial and fungal communities are driven by the plant communities. And so, if we think of it in the context of plant and microbe feedback, as fire regimes shift, so either they're becoming more frequent or burning more severely, it's not just affecting the plants that are on the surface, but it's also affecting the pool of organisms that are available below ground. And so, if those pool of organisms changes, then the pool of microbes that positively interact with plants could also change. And so, we can sometimes think of that in a way of altering, like, vegetation dynamics. At least that's how I've been thinking about it more recently, is like that interaction.

Peyton: So, how can understanding fire adapted traits help managers create a management plan after a fire?

Sarah: I think that is one of the most important things that a manager can understand. And how, I think its management is really tricky. Like, I think we're at a space in the fire ecology world, in which we definitely know we need to learn more, but we do know a lot. And we do kind of know what's working, but in terms of like the practical application of some of those things, I think it's tricky and I think, I definitely think there's a lot of space for more applied science and using the research that we're doing and trying to translate that to managers. There's a lot of really great organizations that do that, or scientists or researchers that are doing those things. But I think managers really care and they also have like a really deep understanding for seeing what's happening on the landscape. I guess maybe like a little quick story is that I participated in a prescribed fire training exchange, and the shorthand of it is called a “Trex.” And I went to Central Oregon, and I went as like, I understand fire ecology from a purely academic standpoint. And I studied treatments, and I know that on paper, we need more fire on the ground, and that prescribed fire is a really effective tool, a management tool, and a lot of these frequent fire adapted forests, which is the Central Oregon ecosystem, is a lot of mixed conifer, ponderosa pine type systems. And I was able to go out with a mixture of people. So I was more on the academic side, but there were people who were very much managers, but a little bit more like they worked for the Nature Conservancy. So, their jobs are to do research, but they do a lot of hands-on applied science research. So, on the other side, we had people who their entire career has been in fire suppression, and they are there to learn more of the practical applications of how to conduct a prescribed fire and qualify for additional training things. And so, I knew that I was lacking that knowledge, and I'm really, really glad that I was able to be a part of that community. And I also was able to give a little talk about what I was seeing and see people's kind of like ears perk up and be like, oh, what we're doing is making a difference in these fire events, like when a wildfire occurs, and we have to make decisions on what assets we want to protect. We know that a treatment with a fire is really beneficial. And so, I really valued seeing these people who, on paper, understanding fire behavior, but then actually seeing it in real life and seeing someone who's maybe didn't learn that textbook definition in the same way that I did, but they have the practical knowledge of seeing it on the ground, I think was really, really valuable. And I'd like to see more of that interaction in doing things in this really cool applied way. And I think there's a lot of opportunity with that with field work, and there's a lot of crossover, but I just wasn't kind of previously exposed to that and had to seek this out. So, I think that's maybe a long-winded way of saying, like, I think it's really important that managers take into account these things, but how do they actually do that? I think it's briefing or just having an understanding of what a system is adapted for and then trying to just bring in as much fire on the landscape as possible. We're in a really interesting time in terms of there are shortening windows to be able to put fire on the ground, and there's also a lot of pressures and concerns. Like, if you think about the North Rim fire that just happened on the Grand Canyon, unfortunately, that was a fire for resource benefit, which is essentially like a natural ignition that managers decide, like, okay, we think that this fire is going to be beneficial, and they got unlucky with weather, and that fire ended up not having as good of outcomes as they wanted. And so, it's really tricky to implement these things, and there's a lot of legal hoops to jump through. And so, I think, like, ultimately, my takeaway is that the management that I've seen is from, like, a prescribed fire perspective. And I know, again, I think Jamie's answer will probably be different than mine, because I'm thinking of it from more like what is good for the trees and not so much what is good for the understory or like wildlife communities. Like, I know I'm missing a lot of those components, and those are really important components to think about. And I'd like to hear someone with that perspective's answer on this question. But yeah, I think ultimately it's just like we know that we need more fire, and we're in a fire deficit, and that impacts everything from when an ignition starts and how that translates to a fire outcome to how that looks when like you have different successional stages for different species, like you don't have regeneration of certain species because they are adapted to fire and they need fire to re-sprout or to germinate. And so, there's all these different components that are at play, and we have interrupted that system and humans have been a part of the fire regime for as long as humans have been humans from my understanding. Like for, I think we're like two million. I'm just spouting things. But yeah, humans have always been playing with fire and using it as they're a part of that system, and we've taken ourselves out of that, and it has really big ramifications. And so, yeah, I think ultimately like understanding specific species adaptations is really important. But from my knowledge, like most people in this field understand that, and it's a matter of just being able to get more fire on the ground.

Jamie: Yeah, my answer kind of goes in a different perspective, which again, is like, I love this. And it's more of how, since most of my research looks at recovery patterns, I often view a management plan for what land managers should do with the landscape after a fire burns through it. And so, we can use fire adaptive traits to, in a way, target where management action is taken. So if a fire burns and it burns within its historic range of variability, so historic range of variability is basically like, not all fires burn the same in a particular area, but there's a range of natural conditions that the, if we're looking at from a traits perspective, that those species are still adapted to it. So, if a fire typically burns 100 years at a high elevation forest, it doesn't always burn every 100 years. It can be like 60 years to like 120. So, like there's a range that like is natural. So, if a fire occurs and it happened within like the range that like those species that are commonly there are adapted to, then we could potentially like tailor our management response to maybe be more passive if we're looking at those adaptive traits. And assuming that the climate is behaving. But in that case, it's more of like a monitoring. So instead of like, I've I'm a little torn on this because my affiliations and my love of forests, but we also have to appreciate the different forms of succession. And so, in some ways, like we can save a lot of money by letting the ecosystem recover itself and monitor and make sure that it's like happening in a way that like meets management expectations, but also environmental expectations. And so, in that, we can use like the fire adaptive traits, too, to think of like what the recovery response should be. So in regards to like Pinyon-Juniper Woodlands, that maybe lack of fire adaptive traits, or they have traits that we haven't quite defined yet, or that we don't really understand, the recovery is going to be much, much slower, but it may also warrant more active management decisions either with seeding native vegetation, maybe not necessarily trees, because trees, as I'm like finding out, like every time I analyze data, like the post-fire area just like doesn't seem to be the best place for opinion. It requires more of an established vegetation. And that's like a link that we need to always remember is that like our trees don't exist in a bubble. Like they rely on like certain environmental conditions to also be met before they can establish. But also thinking of like the microbial world, they provide a few ways that can like help tailor management decisions. So, we can use microbes as an indicator for recovery. So, if the microbial community is establishing how we expect it to with like associations of certain vegetation, we can use that as a way to model ecosystem recovery. And then we can also use beneficial, either bacteria or fungi that like have close ties with certain vegetation as a form of inoculum. This kind of research is still being parsed through on like whether it works or not, because sometimes it doesn't, sometimes it does. Sometimes it works in the greenhouse, and other times in nature it doesn't. But you can use like some kind of inoculum that form beneficial associations with like trees that you are hoping to plant out in order to increase their survival or their growth. So those type of things, they may not be like fire adaptive traits, but they're more trait associations that could help mediate post fire reforestation.

Peyton: So, to wrap up, what is one misconception that people have about fire ecology and fire adaptive ecosystems that you would like to correct? And Sarah, we can start with you.

Sarah: This is a great question, and the first thing that comes to mind is that fire is good, or fire is bad. I hate to use it, though, because it's like such a... It feels, at least like in this realm, it feels like it's so...It's very, very heavily used. And I think that as much as we try to correct those things, yeah, it's still very prevalent. So, I think, I think maybe along the lines of like, we are in a fire deficit is maybe, like maybe the misconception is that we are seeing fire increasing at a scale that we've never seen it before. And that's not quite the whole story. And I've had a lot of conversations with folks that are more on the like management side, or at least in the science communication realm about how do we in a one on one conversation, people understand nuance and that they, when you talk to someone one on one, it's much easier to communicate those things. But I think just generally like the media or where most people, I mean, yeah, our science education is rarely talking about fire ecology, unless you are like in an ecology track or like in a specific setting in which that is important. And so, I do think that people's awareness of fire is increasing, but the fear of fire I think is also increasing. And I find myself guilty of that as well, even though this is what I study and see myself continuing my career in. For example, when the Alexander Mountain Fire was occurring last summer, it was a little nerve-racking. It was super dry, and we hadn't had rain in a while, and it was right outside of Loveland, and it was definitely nerve-racking in that moment. And there were homes that were lost, and it was really challenging and traumatic for the community that was impacted by it. And ultimately, my understanding is it was a really beneficial fire, ecologically, that it burned at relatively low to moderate severities, and that it did a lot of really good work and is potentially going to protect the community of Loveland for a while. And so, those two things are true. Like, it is scary, and it is, has the potential to be really, really devastating for communities and people. And it also is so important for it to be on the landscape, and we need more of it. We just need more fire that isn't happening under conditions that are beneficial for it to be a "good fire." Yeah, so I think maybe just like taking away the good and bad of fire and saying that it has a lot of nuances and that we have to work with fire. Like the fire paradox is very, very real. And that we can't have just good fire. Or actually, maybe my argument is we can have just good fire. We just have to do a lot of work to get there.

Jamie: Yeah, it really is challenging because we want fire, but we just want it away from us. We want it away from our communities, or we want our communities to be hardened, to be able to withstand it if the fire were to get close and become more of a risk. So, there is that big fear aspect for sure that is really understandable for the community that may not recognize all the benefits. We just need to convince them more. As scientists, though, I feel, and maybe people that live close to fire, maybe there's become a little bit of a shift, at least from what it was before, that like fire can be restorative. And even like, there's like this cognitive dissonance, it seems, where we recognize fire is natural, fire is good. Fire is fire, it exists. It keeps our ecosystems in balance. Balancing fire, maybe. I don't know, I'm just coming up with new words. But it's so easy to have that emotional reaction when a place that you love burns. Like, your favorite hiking spot is, it's not what it was before. And it's total, like, human emotion to just, like, we like how we like things. And so, I guess if I could remove it from people's brains, that, like, we can also enjoy the recovery process. Like, the recovery conditions of forests are also very beautiful, like, especially after the fire, we have so much, like, native wildflowers that come up that weren't there before the fire. But now we have a beautiful temporary meadow that's really lovely to walk through. And then later on, perhaps, like, some shrubs come up, and those are stunning to be around in the fall. You get, like, so many different colors that you hadn't seen in that same forest. So just, like, I want everyone to enjoy observing succession. I don't know. It's a really, like, astonishing thing to see. And, yeah, that's what I would like to correct.

Peyton: Those were great answers. Thank you, guys. I really appreciate you guys taking the time out of your busy schedules to talk with me a bit and, you know, give me your opinions and expertise and talk about your work. And I think this is a great way for me to finish off this mini-series with some people who have actually worked with fire and see the impacts it has. So, thank you.

Jamie: Thanks for having us.

Sarah: It was fun. It's fun to talk about our work with people who are excited about what we do.

Peyton: Today's conversation reminded us that fire is a powerful driver of change and renewal in many ecosystems. From the microbial communities to the entire vegetation and habitat, each level of an ecosystem has its own way of adaptation and resilience. As climate change continues to alter our historical fire regimes, understanding these adaptations is becoming more critical to managing resilient ecosystems for the future. And with that, we've reached the end of this mini-series. Over the past five episodes, we've discussed adaptations, correcting the common misconceptions around them, and explored the multiple ways that fire shapes our landscapes. We've discussed resilience, endurance, and other creative ways nature has survived when faced with fire. A huge thank you to our guests for sharing their work and stories. Also, thank you to Dr. Jennifer Neuwald and Dr. Sarah Hart, my advisors on this project. They have both taken countless hours out of their busy schedules to help me with this mini-series, and I cannot thank them enough. I hope this series has taught you to appreciate fire adaptations and the stories behind them. I'm your host, Peyton, and this has been Ashes and Adaptations. Thank you for listening.

Episode 5 Sources:

Fire Behaves Differently in Different Forest Types. Colorado Forest Restoration Institute. (2021, January). https://cfri.colostate.edu/wp-content/uploads/sites/22/2021/01/FireEd-Infographic-Web_Print-1.pdf

Section II

Reflection Paper

“Ashes and Adaptations” is a five-episode podcast mini-series discussing plant adaptations shaped by fire. The goal of the project was to create an overview of fire as an evolutionary force and explain how climate change is harmful to fire-adapted ecosystems. The audience was intended to be the general public, not just those within the scientific community. By working with Dr. Neuwald and Dr. Hart as advisors, this podcast was able to come into fruition. This project combined many of the skills I have fostered throughout my undergraduate experience, including research and writing, while also utilizing the knowledge I have gained from my classes in natural resources.

The idea for this project originated in Dr. Neuwald’s Evolution course and its connected honors option. I found this course incredibly engaging, and I felt that it deepened my overall understanding of ecosystem processes and interactions. This experience sparked my interest in exploring evolutionary principles in real-world ecological dynamics. After this, I knew that I wanted my thesis to relate to evolution and scientific communication in some way. However, I was unsure of the most effective method to use.

After meeting with Dr. Hart, I was reminded of a project I had completed for her Silviculture course, a podcast. As someone who frequently listens to podcasts, I had found this project particularly enjoyable and creatively fulfilling. Unlike traditional projects, such as lab reports or research papers, the podcast allowed me to merge science with storytelling, creating an incredibly effective way to communicate complex scientific concepts. This experience made me realize that creating a larger-scale version of this project for my thesis would allow me to explore both my scientific interests and develop my scientific communications skills.

The final piece of the puzzle was my fire ecology course, taught by Dr. Stevens-Rumann. In this course, I was intrigued by the role of fire as a natural, and even essential, ecological force in many landscapes. It became clear that exploring fire adaptations would be a perfect focus for my thesis, combining my interests in evolution, fire, and scientific communications. By merging these influences, I was able to design a project that is personally meaningful and academically rigorous.

Despite my previous experience in Dr. Hart's course, I was still quite inexperienced with podcast creation going into this project. One major issue I faced was underestimating the amount of effort involved in producing a single podcast episode. During my pre-thesis course, I greatly overestimated my abilities and initially claimed that I could create ten episodes for this project. Luckily, I was advised against this. However, I repeated this pattern later and assumed that 45-minute-long episodes would be manageable. I quickly realized that I simply did not realistically have the time to create multiple 45-minute-long episodes by myself. Writing the scripts, recording the episodes, and editing the episodes proved to be far more time-consuming than I had anticipated. Even shorter 10-to-15-minute episodes required about two hours each to record and edit. Because the first four episodes were fully scripted, I aimed to exclude any filler words or stuttering. This required multiple takes for each section of the script. However, I recognize that someone with more experience in this realm likely could have completed this much faster. As I became more proficient with the editing software, I found that the workflow became much easier. Overall, this aspect of the project taught me to manage my expectations and be honest with myself regarding my own abilities.

Another issue I struggled with was catering this podcast to a general audience. While I quickly learned that shorter episodes were more realistic for my abilities and the time constraint, I also learned that shorter episodes were more accessible. A quick search into the most popular science podcasts reveals that they come in a wide variety of episode lengths. However, I felt that the longer episodes could seem daunting to a listener that does not have a science background. I wanted this to be an easy way for anyone to learn about evolution and fire adaptations on their drive to work. Thus, I chose to begin my series with an overview of evolution. This allowed for every listener to be on the same page going into the series. This episode explained the mechanisms behind evolution, how adaptations work, and corrected common misconceptions about the topic. I felt that this episode would be an accessible introduction to evolution and make the series as a whole feel less daunting for those without science backgrounds. It also allowed for the rest of the series to focus more on the topic of each episode without having to go off on tangents explaining an evolutionary concept.

The next couple episodes focused on thick bark, serotiny, and eucalyptus trees. I chose thick bark and serotiny because they’re extremely common adaptations to fire. Therefore, I thought that they would be an excellent introduction to the topic. Also, thick bark is mainly seen in ecosystems characterized by a frequent, low-severity fire regime while serotiny is commonly seen in ecosystems with an infrequent, high-intensity fire regime. This allowed for a discussion of fire regimes and tangible evidence of how differences in a regime impacts the system’s characteristics. Next, eucalyptus trees contain various fire adaptations that allow them to survive or regenerate after a wide variety of fires. This allowed for a discussion of various adaptations within one episode. Because I did not have the ability to create an episode on each of these characteristics, the eucalyptus tree allowed me to combine them all into one concise episode. If I had more time, I would have made each of these traits into an episode of its own.

The final episode of the mini-series was a panel discussion with two scientists in the field of fire ecology: Jamie Woolet and Sarah Hettema. Jamie is a PhD candidate at Colorado State University, and Sarah Hettema is a recently graduated master's student that now works on landscape level wildfire treatment outcomes. I wanted to have professionals in the field give their opinions on current issues in fire ecology to ground the series. This episode allows listeners to connect the fire adaptations they have been learning about to broader concepts in ecosystem management today. I had never hosted a panel discussion before, so I was incredibly nervous for this event. Luckily, it went very well and ended up being a lot of fun. Jamie has more experience with specific impacts of wildfires on ecosystems, such as the soil composition or wildlife. On the other hand, Sarah has more experience with wildfire impacts on a larger scale, looking at the overall health of the ecosystem after a fire. Having both perspectives created a comprehensive discussion of wildfire's impact on a system. I felt that it was crucial to include voices that are doing work today because they are actively seeing the impacts climate change is having on fire-adapted ecosystems. Sarah specifically had interesting stories of working with managers and learning how to apply her scientific background to land management. This allows listeners to use the knowledge they have gained from previous episodes to understand issues occurring in natural resource management today.

This podcast mini-series allowed me to combine the scientific knowledge I have gained throughout my undergraduate experience with my interest in scientific communication. The process of creating a podcast proved to be a serious undertaking that forced me to step out of my comfort zone. It forced me to take a step back and consider how to effectively explain complex scientific concepts to a general audience. In the face of climate change, this is an essential skill for scientists to have. If we are unable to explain these concepts to everyone, we cannot make the steps necessary to mitigate the climate crisis.

Acknowledgements

I want to first and foremost thank my advisors on this project: Dr. Neuwald and Dr. Hart. Their extensive help on this was paramount to the fruition of this mini-series. They took countless hours out of their busy schedules to review my scripts and offer advice. I cannot thank them enough for their constant guidance and encouragement throughout this process.

I also want to thank my family and friends for their continual reassurance throughout this project. Without my parent’s support, I would not be in the position I am today. This podcast was a large undertaking for my final semester of my undergraduate experience, but I am incredibly grateful to have had the opportunity to create something I care about.