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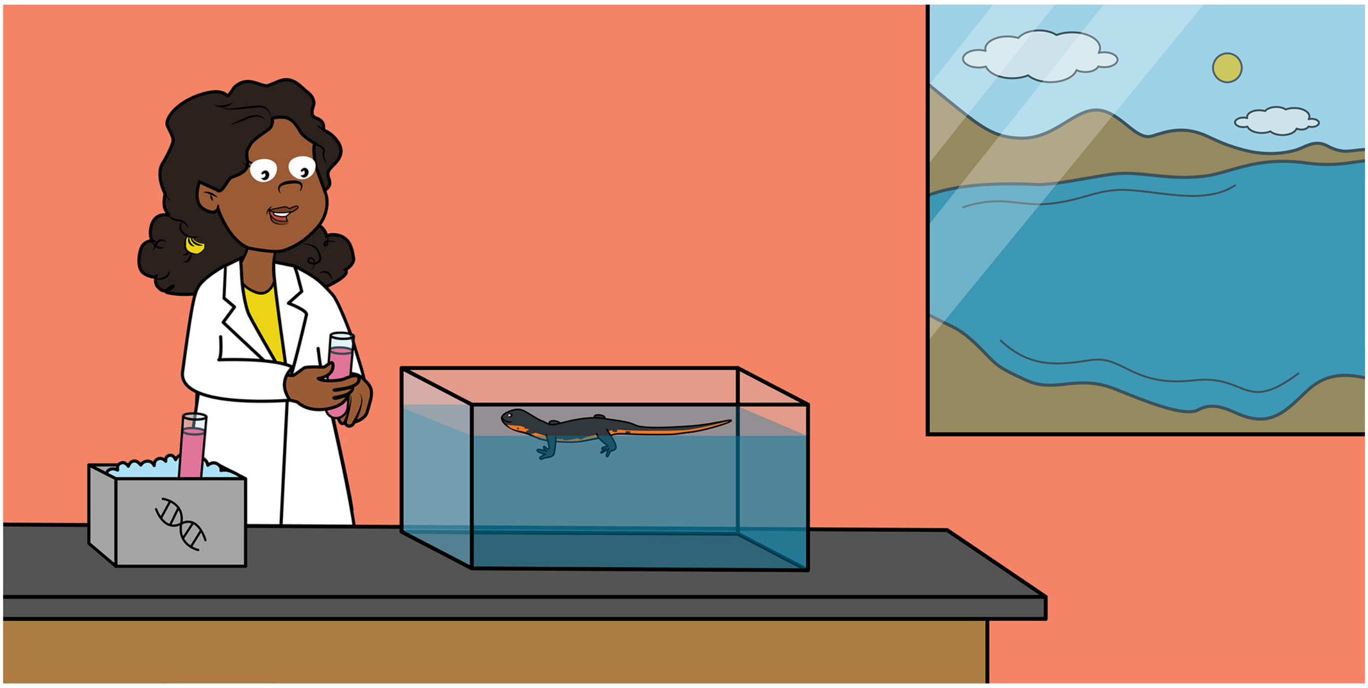

CRACKING THE MYSTERY OF CRATER LAKE'S UNIQUE NEWTS

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YOUNG REVIEWERS:


ADELAIDE
AGE: 7


LUKE
AGE: 10


SILAS
AGE: 12

Why does Earth have such an incredible variety of plants and animals? One little newt helps tell the story. In Crater Lake, the world's clearest lake, a uniquely colored newt was discovered. Early explorers named it the Mazama newt. For more than 100 years, the newt has been considered a subspecies of the more common rough-skinned newt. A "subspecies" refers to a collection of animals or plants that can interbreed but can often be separated from other individuals of the same species by appearance. Nobody knew exactly how unique the Mazama newt was until scientists took another look. Using a mix of clues, like DNA, skin color, and even poison levels, scientists are cracking the mystery of how the Mazama newt differs from its neighbors. Learning about the newt's unique characteristics and about other members of the Crater Lake ecosystem is important for protecting biodiversity and lake health.

SO MANY SPECIES ... SO MANY ENVIRONMENTS

For centuries, scientists have been cataloging Earth's species. Tens of thousands of new species are discovered each year. Some scientists believe the Earth contains 8–10 million species [1]. Plants and insects have the largest variety of species within the macroscopic (large enough to see with our eyes) groups of life. Tropical forests and coral reefs are the most species-rich places on Earth.

The vast number of species shows that Earth contains an unimaginably large number of habitats. These various habitats provide conditions that support the life of one or many species. Different conditions influence where a species can feed, live, grow, and reproduce and do so for generations. Throughout Earth's history, disturbances like earthquakes, fires, and floods have been destroying habitats and removing species. At the same time, disturbances create new habitats for species to colonize. Some disturbances create barriers that prevent groups of animals from the same species from interacting. Scientists call isolated groups of the same species **populations**.

POPULATION

A group of individuals of the same species that can interbreed and exchange genetic information. Populations are often isolated from each other.

If two groups of a single species are separated long enough, new species can evolve. This process takes many thousands of years. It occurs when separation prevents individuals from the same species from breeding and exchanging **genes**. Genes are unique regions of DNA that code for the **traits** (physical characteristics) of organisms. Genes can be used to understand how individuals or populations are related. When populations are separated for many generations, genes, traits, and behaviors become different between the two groups. As disturbances on earth occur, so too will the separation of populations and the evolution of new species.

GENE

A specific sequence of DNA that is transferred from a parent to offspring and contributes to characteristics of the offspring.

TRAIT

A characteristic, like color, passed on from parents to offspring.

VOLCANOES, EARTHQUAKES, AND FLOODS ... OH MY!

Volcanoes, earthquakes, floods, melting glaciers, and fires are disturbances that dramatically change habitats. Volcanoes, like Mt. St. Helens, explode, rearrange mountain tops, and deposit ash over large areas. Melting glaciers uncover ground that has not been exposed for thousands of years. Humans also play a role in the creation of habitats. Dams are built, holding back rivers to create lakes in previously dry areas. Disturbances can create new habitats that species can move into.

In Crater Lake National Park, a massive volcanic eruption removed the top of a mountain to create present-day Crater Lake. This started 30,000 years ago, when Mt. Mazama began erupting and changing the landscape where the park now sits. After the last major eruption 8,000 years ago, and with its magma chamber nearly empty, Mt. Mazama collapsed. It left a crater, called a **caldera**, 8–10 km wide and over 1 km deep. Over the next 1,000 years, snowmelt accumulated and formed

CALDERA

A crater formed by a major volcanic eruption that causes the collapse of the mouth of the volcano.

a lake within the caldera—Crater Lake (Figure 1). This lake was isolated from surrounding lakes and nestled within the tall, steep walls of the former volcano's crater. Animals and plants colonized this new habitat, and this is how the story of the Mazama newt began.

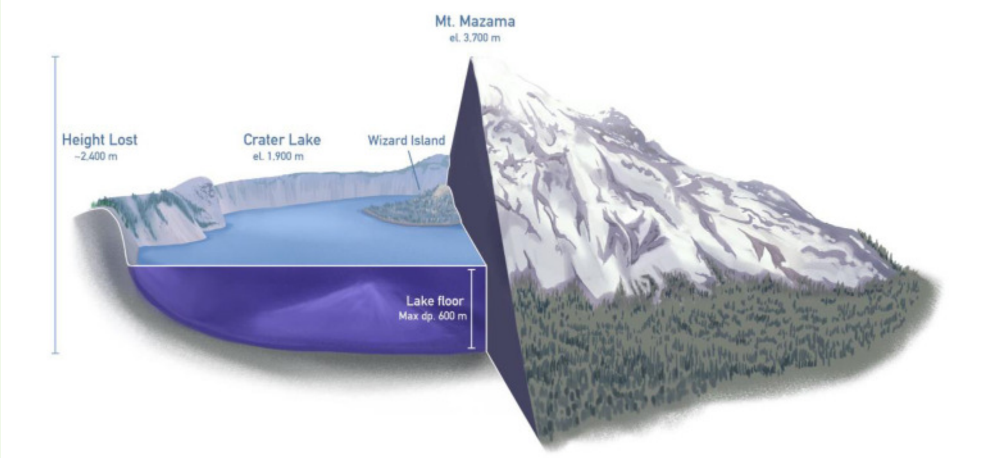

Figure 1

Figure 1

On the right is an artist's imagined view of Mt. Mazama, a mountain that stood approximately 3,700 m tall in southwest Oregon, USA, before it erupted and collapsed nearly 8,000 years ago. The Crater Lake caldera was formed from this collapse. On the left is a cross-sectional view of Crater Lake today. After the Crater Lake caldera formed, additional eruptions formed Wizard Island. Wizard Island and other volcanoes continue to grow to this day—one of which is shown underwater in this image (Image credit: Elena Hartley at www.elebarts.com).

THE MAZAMA NEWT

Early park naturalists focused on one particular Crater Lake colonizer. They noted the unique appearance of Mazama newts and thought that they were a **subspecies** of rough-skinned newts [2]. Subspecies are related species that can interbreed but can typically be distinguished by differences in appearance and DNA sequence. Rough-skinned newts are a common species across the U.S. Pacific Northwest and Canada, from central California to southeast Alaska. Rough-skinned newts are brown on top with a bright, orange-colored underbelly (Figure 2). The orange belly warns others that the newt is poisonous. That is right, the skin of rough-skinned newts contains a deadly poison (called tetrodotoxin) that protects them from predators, including garter snakes. Outside the caldera, rough-skinned newts spend summers in small ponds eating insects. They spend winters in the forest, inside rodent burrows. In high-elevation lakes like Crater Lake, rough-skinned newts have adapted to overwinter within the lake itself!

SUBSPECIES

In taxonomy, subspecies is a classification that falls within species. Subspecies can interbreed but can often be separated from other individuals of the same species by appearance or genetic information.

The current hypothesis for how the Mazama newt evolved is that nearby rough-skinned newts entered the newly formed lake after the dust from the Mt. Mazama explosion had settled. Because of the steep walls of the crater, newts that entered likely did not migrate back out. This means that two groups of rough-skinned newts were separated. The group within the crater began accumulating differences in genes, traits, and behaviors that allowed those newts to survive in Crater Lake, a very different habitat from the one in which their ancestors lived.

Figure 2

Figure 2
Examples of the coloration patterns on the belly of a Mazama newt from Crater Lake (left) and a rough-skinned newt from nearby Spruce Lake, Oregon (right).

We used a series of clues to test the hypothesis that Crater Lake's newts are different from newts in ponds and lakes outside of the caldera. Specifically, we compared the orange belly color [3], which advertises the newts' toxicity, as well as the newts' weight-to-length ratio, which is an indicator of their health. We also compared the poison levels between groups of newts [4]. Additionally, we explored information locked inside newt DNA. While biologists have used clues like color and size for centuries to separate species or populations, genetic tools provide even more powerful clues. Exploring the DNA code can uncover similarities and differences among populations based on their shared history. Think of a family tree that goes back thousands of years!

CRATER LAKE'S NEWTS ARE … DIFFERENT

Crater Lake's newts have darker bellies, often with black leopard-like splotches or tar-like smears (Figure 2). Newts in Crater Lake are also skinnier compared to newts in habitats outside of the caldera. Interestingly, tetrodotoxin levels in Crater Lake newts are among the lowest levels measured.

Traits such as weight, color, and poison levels are signs that Crater Lake newts might indeed be an unusual group. Such differences can also be due to different environments even within the same population. The evidence that most clearly tells us that Crater Lake newts are different from all other rough-skinned newt populations can be seen by looking at their genes. Every gene has multiple forms that are slightly different in their genetic code. These differing forms of the same gene are called **alleles**. Groups of newts that are closely related will have similar combinations of alleles. A population of newts that is isolated will have a different set of alleles common to that population. The most common alleles in newts in Crater Lake are different from those of newts anywhere else in Oregon (Figure 3)! In fact, we can tell if a newt came from Crater Lake just by looking at these genetic clues. This is even more striking because all other rough-skinned newts sampled in Oregon tend to be similar genetically, even from ponds hundreds of kilometers apart.

ALLELE

Alternative forms of a gene resulting from small changes found at the same place on the chromosome of different individuals.

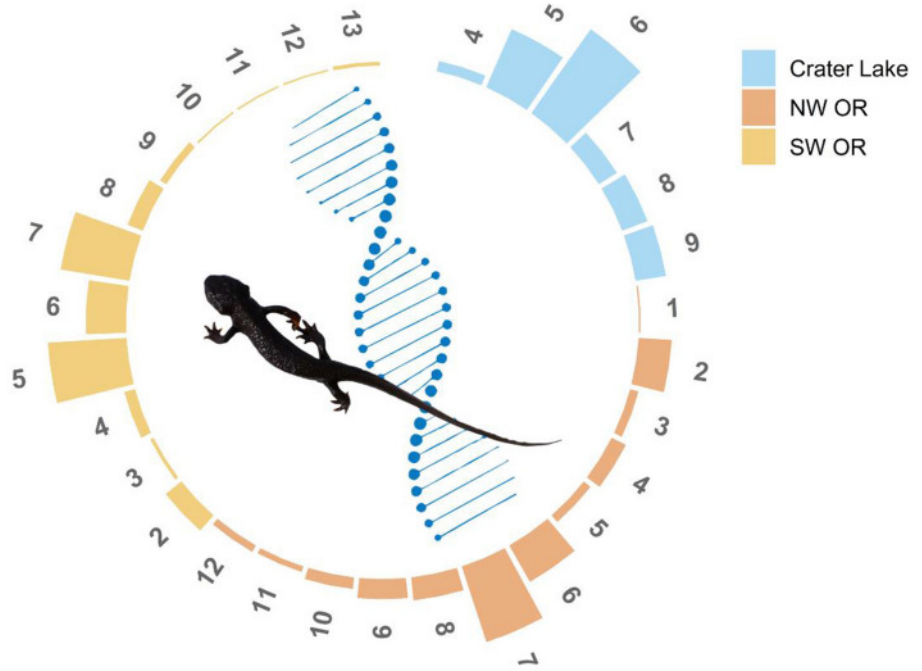

Figure 3

Figure 3

Separation between newt populations created differences in the number and relative proportion of individual alleles within each population. The circular bar graph shows alleles at a single gene for three newt populations: Crater Lake, southwest Oregon (SW OR), and northwest Oregon (NW OR). Individual alleles are represented by a numbered bar. Taller bars indicate a greater proportion of that allele relative to other alleles. Crater Lake newts have fewer alleles (fewer bars) and there is a greater proportion of allele 6 compared to other areas. Although this example shows one gene, scientists typically use many genes to describe genetic isolation.

DIFFERENT, BUT HOW DIFFERENT?

Differences in traits like color, weight, and poison levels show that newts in Crater Lake have adapted to conditions in Crater Lake. In nature, small variations in traits and genetic codes are expected among individuals or populations. However, the stark differences reported here are evidence that individuals from different populations of the same newt species are not regularly interbreeding and exchanging genes.

When breeding is prevented by a barrier, like a mountain top or a highway, differences in characteristics, behaviors, or allele numbers and proportions can change over time. In the case of the Mazama newt, the steep, rocky caldera walls may have served as a natural barrier. We hypothesize that the near-vertical walls blocked all but an occasional newt from trekking down into the lake. Our DNA data suggest that this trek *into* the lake *does* rarely happen, but the reverse scenario, in which newts from Crater Lake move up the caldera walls to breed in outside ponds, does *not* happen.

So, if Mazama newts are measurably different than rough-skinned newts but they are *not* a different species, then what are they? We believe that the differences described here are representative of an isolated population adapted to local conditions—conditions present only within Crater Lake. Adaptations to unique conditions are called **adaptive variation**. Isolation of newts within Crater Lake means that the alleles of the Crater Lake newt population are accumulating measurable differences, generation after generation. Since this population is still part of the wide-ranging rough-skinned newt species, it also means that Crater Lake's newts are expanding the overall **genetic diversity** for this species. This increased genetic diversity may be slight, but genetic diversity is a component of the overall biodiversity of national parks. Biodiversity, the total number of genes, species, and habitats of an area, is important because it provides a measure of ecosystem health and protecting genetic diversity helps species to better survive changing environments especially with ongoing climate change. In Crater Lake, dark-colored newts have confused scientists for more than a century, but now we better understand how a volcanic disturbance added to the genetic diversity of rough-skinned newts.

ADAPTIVE VARIATION

Genetically linked variation in color patterns and other traits that contributes to differences in survival and reproduction among individuals in the wild.

GENETIC DIVERSITY

The diversity of alleles at genes present within a species.

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YOUNG REVIEWERS

ADELAIDE, AGE: 7
My name is Adelaide and I love to ski, camp, hike, and bike. I also love arts and crafts and my favorite color is blue. I love stuffed bears, cats, and dogs. I love to paint, and I want a dog. I love to be outside.

LUKE, AGE: 10
I like skiing, mountain biking, and fishing. I like legos and getting dirty. My favorite subject in school is math and I want to be a scientist when I grow up.

SILAS, AGE: 12
I really like to ski and snowboard. I also really like hanging out with friends and playing video games. I love music, so I play piano and drumset. My favorite subject in school is language arts.

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Andrew M. Ray is an ecologist with the National Park Service's Greater Yellowstone Network in Bozeman, Montana. Andrew received his B.S. from Purdue University, an M.S. from Northern Michigan University, and a Ph.D. from Idaho State University.

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Scott F. Girdner is an aquatic biologist at Crater Lake National Park, Oregon, where he manages a long-term lake-monitoring program of the deepest lake in the United States and one of the clearest lakes in the world. He began his studies of inland waters at the Institute of Limnology in Uppsala, Sweden while getting a B.S. in biology from Chico State University. Scott received his M.S. from Oregon State University, studying high mountain lakes in Mount Rainier National Park, Washington. His work revolves around mountain lakes and using long-term monitoring of protected areas for answering scientific questions.

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David K. Hering is an aquatic ecologist at Crater Lake National Park. His interests include life history diversity and behavior of freshwater fish, the effects of invasive species, and conservation of native fish and amphibians. For 14 years, Dave has worked to protect imperiled populations of trout in Oregon's Upper Klamath Basin. His work emphasizes collaborative partnerships to accomplish ecological restoration. Dave recently assisted a project to restore an alpine lake ecosystem in Slovenia. He holds a M.S. in fisheries science from Oregon State University. Dave lives in Ashland, Oregon with his wife and two daughters, who also enjoy science.