

## *The Making of the Fittest: Natural Selection and Adaptation*

**[NARRATOR:]** Across the American Southwest, golden deserts, dotted by cacti and brush, stretch for miles. Yet here in New Mexico's Valley of Fire, the landscape changes dramatically. Patches of black rock interrupt the sand, remnants of volcanic eruptions that occurred about 1000 years ago. The eruptions spewed a river of lava more than 40 miles long, across the desert. As the molten rock cooled, it darkened, leaving any creature dependent on camouflage in serious trouble.

**[DR. CARROLL:]** In the complex battle of life, one of the constant struggles is between seeing and not being seen, the evolutionary game of hide and seek. And we've come here to the valley of fire in New Mexico, a battlefield, to find one of the tiniest soldiers and what it can teach us about how evolution works.

**[NARRATOR:]** On the desert sands, the rock pocket mouse blends in perfectly, its light-colored fur concealing it from predators. But on dark lava, the same fur makes the mouse stand out, attracting the many creatures that see it as food.

**[DR. NACHMAN:]** These mice are the Snickers bar of the desert. They're eaten by foxes, and coyotes, and rattlesnakes, and certainly by owls and maybe even occasionally hawks. And most of those predators are visual predators.

**[NARRATOR:]** So what happened to the pocket mice that found themselves on this new terrain? When I accompany biologist Michael Nachman onto the lava, it doesn't take long to find out.

**[DR. NACHMAN:]** Oh, this one is closed.

**[DR. CARROLL:]** Does it have something in it?

**[NARRATOR:]** Nachman has been collecting mice, unharmed, in traps.

**[DR. CARROLL:]** And it's a dark one.

**[DR. NACHMAN:]** It is.

**[DR. CARROLL:]** Now are most of the ones you find up here dark?

**[DR. NACHMAN:]** Almost all of them.

**[NARRATOR:]** Not only have the mice here evolved to be as dark as the rock, the color change has occurred precisely where it will conceal them from hunters.

**[DR. CARROLL:]** It has a bit of a white underbelly too.

**[DR. NACHMAN:]** That's right. All of the dark ones here and on other lava flows have a white underbelly and presumably there is no selection for dark on the belly because predators are coming from above.

**[NARRATOR:]** Left to themselves, the mice show no preference for light or dark rocks. It's the predators that have made the difference.

**[DR. NACHMAN:]** The change in color over evolutionary time in the population is driven by predators weeding out the mice that don't match their background.

**[NARRATOR:]** But how did the dark mice arise in the first place?

**[DR. NACHMAN:]** When a black mouse appears in a light population of mice, that is usually going to be due to a new mutation. And those are random and rare events.

**[NARRATOR:]** To fully understand the pocket mouse transformation, Nachman moves from the lava to the lab. He and his team extract DNA from light and dark mice taken from one desert region. The aim? To find one or more genetic mutations that caused dark coloration. A mutation is a change in the chemical letters that make up our genes. It's a copying error that may occur when our cells divide.

**[DR. CARROLL:]** Mutation seems to mean that something bad has happened. Well, mutations are neither good or bad. Whether they are favored, or whether they are rejected, or whether they're just neutral, depends upon the conditions an organism finds itself. So, for the pocket mouse, a mutation that caused the mouse to turn black, that is good if you're living on black rock, and it's bad if you're living out in the sandy desert.

**[DR. NACHMAN:]** The light mice are all on the bottom: here, here, here...

**[NARRATOR:]** Fur color is a trait controlled by many genes. To figure out how dark mice evolved, Nachman focuses on how these genes differ in dark and light mice. One by one the genes prove identical. But at last, something does turn up. The difference between dark and light mice boils down to a difference of four chemical letters in a gene called MC1R. Because the gene controls the amount of dark pigment in a mouse's hair follicles, a mouse with these mutations grows dark fur, which gives it an advantage on a dark background. But still, that's one mouse. How would its dark fur spread to a whole population?

**[DR. NACHMAN:]** This lava flow is about a thousand years old. And so you might wonder, has there been enough time? It's only been a thousand years. It's a very short period of time for a new mutation to come along and spread, so that all of the mice on this lava flow are black. Because really, they all are.

**[NARRATOR:]** Indeed, such a rapid spread of a mutation may seem unlikely--until you do the math.

**[DR. CARROLL:]** And the reason is, that while only one new mouse born in 100,000 may be black, hundreds of thousands of mice are born in any given year. And then those mice that are black have enough advantage that their babies do better and they have more offspring. And their offspring have more offspring. And just about a 5% advantage compounded year in and year out can very quickly turn the whole population black as we see today.

**[NARRATOR:]** If dark color gives mice a 1% competitive advantage, and you start with 1% of the population being dark, in about 1000 years, 95% of the mice will be dark. If instead the dark color gives them a 10% advantage, then it only takes 100 years. Thanks to Nachman's mice, science has an example of evolution, crystal clear in every detail.

**[DR. NACHMAN:]** What's exciting about this is that we have a system that's very simple ecologically. You have dark rocks and you have light rocks. And you have dark mice and light mice. It couldn't be simpler.

**[DR. CARROLL:]** We know who the predators are, what the selective force is. We know precisely the genetic basis of what makes the mice have an advantage or a disadvantage depending upon where they live. All the pieces are finally together. It's a perfect illustration of Darwin's process of natural selection.

**[NARRATOR:]** In fact, it's more than that. For Nachman's mice also counter a common misconception: that evolution is a random process.

**[DR. CARROLL:]** Well, there is one random component, and that's the process of mutation. Mutations occur at random throughout our DNA. Every new organism is born with a new set of mutations. But while mutation is random, natural selection is not. Natural selection sorts out the winners and losers and that's really what the whole process of evolution is driven by.

**[NARRATOR:]** But if natural selection is not random, would it produce the same result under the same conditions?

It does. And here's proof. Rock pocket mice collected by Nachman from other lava flows in other parts of the Southwest.

**[DR. NACHMAN:]** These are two different black mice and they each evolved on different lava flows. And the lava flows are hundreds of miles apart but the changes, the genetic changes that made these mice black, were different in each case. And what's amazing to me is how similar the black mice are. We didn't know when we started this whether we would find that they were the same genes or different genes. And we were really surprised to find that they were completely different genes. And yet, if you look at the mice they look almost identical.

**[NARRATOR:]** Clearly, there are different genetic ways to make a mouse dark. But once the beneficial mutations appear, natural selection, the non-random part of evolution, can, under very similar conditions, favor very similar adaptations.

**[DR. NACHMAN:]** In effect, each of these lava flows is like rewinding the tape of life and allowing evolution to occur again and again. And in each case, we find the dark mice have evolved.

**[NARRATOR:]** The rock pocket mice show us that evolution can and does repeat itself...and why evolutionary change is never-ending. As environments transform, so must the species that inhabit them, adapting and re-adapting in the great and complex battle of life.