Stanford biologist explains science of superheroes' origin stories (w/ Video)

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Captain America and the Incredible Hulk are two of our most iconic comic book superheroes, but little is known about how they came to possess their superpowers. Stanford biologist Sebastian Alvarado has the answer: epigenetics.

In the colorful pages of comic books, a swig of an experimental elixir or accidental exposure to a ridiculous amount of radiation can turn a mere mortal into a super-being.

The comics and movies gloss over some of the scientific principles of how these processes turned normal humans into Captain America and the Incredible Hulk, but Sebastian Alvarado, a postdoctoral research fellow in biology at Stanford, has a few ideas.

The key to these characters' transformations, he said, might involve some cutting-edge genome-editing techniques.

An all-American hero story

The origin story of Captain America is, well, storybook. It's World War II, and a bony, 90-pound weakling named Steve Rogers desperately wants to join the Army to fight for his country. Deemed too frail for the front lines, Rogers is instead recruited into a top-secret experiment. He's injected with a "Super-Soldier Serum" and blasted with "Vita-Rays," and is instantly transformed into a broad-shouldered soldier with off-the-charts strength, stamina and intelligence.

In the past 70 years, scientists haven't created a real Super-Soldier Serum recipe, but they have identified the specific genes involved in increasing muscle mass and improving the oxygen-carrying load of blood. They also have developed tools for selectively activating and deactivating individual genes like flipping a light switch, a process termed epigenetics.

"We have a lot of genome-editing tools – like zinc finger nucleases, or CRISPR/Cas9 systems – that could theoretically allow you to epigenetically seek out and turn on genes that make your muscles physically large, make you strategically minded, incredibly fast, or increase your stamina," Alvarado said.

These tools and their specific instructions could be packaged in capsules that are being developed by pharmaceutical companies. That's where the

Vita-Rays come in – these drug-delivering capsules can be designed to release their contents only when subjected to certain wavelengths of light. Several current systems involve ultraviolet light, but they probably could be triggered by whatever wavelength constitutes Vita-Rays. Simply inject the capsules containing instructions for, say, muscle growth into Rogers' major muscle groups and give them a zap of UV light.

"Of course, at this point, these types of things have been explored mostly in lab mice," Alvarado said. "But it's fun to speculate."

An 'incredible' origin

Unlike Steve Rogers, Bruce Banner didn't sign up to become a superhero. The details have changed slightly over the years, but his story basically goes like this: Banner, a brilliant physicist, gets caught in a tremendous gamma ray explosion. Miraculously, he survives the radiation, but now he has a tendency to transform into a giant, invulnerable, super-strong beast, otherwise known as the Incredible Hulk.

Explaining Banner's transformation into the Hulk takes a little more creativity, Alvarado said, but there are a few principles that, if stretched just enough, could provide an explanation.

First, when gamma radiation hits DNA, it breaks the molecule's double-stranded, ladder-like helix, a process known as chromothripsis. Your body can repair a few breaks without significant loss of function.

If many breaks occur – say, if you were caught in a giant gamma explosion – the repairs can become sloppy, and new instructions can be keyed into the genetic code. Alvarado suggested that it's possible that when Banner's DNA reassembled after the initial blast, it now included a handful of epigenetic switches. Instead of the switches being activated

by light, however, the hormones produced when Banner is angry might flip the genetic switches to reconfigure his DNA to transform him into the big, green Hulk.

As for the Hulk's skin turning green, anyone who has suffered a nasty bruise has firsthand knowledge of the process that might be behind this transformation. When you bruise, red blood cells at the point of injury die and the oxygen-carrying molecule on their surface, hemoglobin, begins to break up. One of hemoglobin's metabolites, Alvarado said, is a molecule called biliverdin, which can make the blood appear green and is responsible for the avocado hue at the edge of a bruise.

"Bruce Banner's transformation into the Hulk would be incredibly traumatic to his body, and maybe his green skin is the result of a whole-body bruise," Alvarado said. "If you want to get really creative, maybe his blood is full of some sort of green Hulk-oglobin, which can carry more oxygen to the muscles than hemoglobin and gives him his strength and stamina."

There's still one mystery about the Hulk that science can't solve, Alvarado joked: How do his pants stay on after every transformation?

Alvarado's effort to bring these superheroes' origin stories into closer agreement with modern science is part of his work with Victory Hill Exhibitions, which produced the interactive Avengers-based exhibition, called Marvel's Avengers S.T.A.T.I.O.N., in Times Square in New York City.

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