Rolling stones, turbulence connect evolution to physics

February 17 2016, by Ken Kingery

Adrian Bejan, the J.A. Jones Professor of Mechanical Engineering at Duke University Credit: Duke University

A law of physics explaining why larger animals live longer and travel further also extends to the simplest forms of mass migration on the

planet—like rolling stones and turbulent eddies in water and air currents, according to research at Duke University.

The finding demonstrates that evolution doesn't apply only to biological things, but any physical system in motion, says Adrian Bejan, the J.A. Jones Professor of Mechanical Engineering at Duke.

Ten years ago, Bejan developed a physical law called the constructal law, which states that any flowing system allowed to change freely over time will trend toward an easier flowing architecture. For rivers, roots and vascular systems, this means a few large channels carry massive flows to numerous smaller branches for dispersal. Similarly for animals, a few large species with extensive, long-range impacts on the environment act together with many smaller species affecting smaller regions, but in greater numbers.

In a paper published February 17, 2016, in the journal *Scientific Reports*, Bejan shows this idea can be generalized even further. He posits that the most basic processes that have shaped the planet's landscape for billions of years—rolling stones and turbulent water currents—also adhere to these physical laws.

"I'm defining evolution literally to mean what the word implies, which is continuous change in a discernible direction over time," said Bejan. "It's a movie. What Darwin imagined for animals and called 'evolution' is actually a physical description, and it applies to everything else that morphs freely while flowing, whether it's biological or not. So my 'aha' is that evolution is everything, because everything is in motion and is free to change while moving."

In his thought experiment, Bejan went through a series of simple physics equations showing that both the time spent moving and the distance traveled of a rolling stone should increase with its mass. He then

demonstrated that an eddy of turbulence can be thought of as a fluid eye rotating in a fluid socket, and that its lifespan and traveling distance also increase with its size.

Both processes have been responsible for moving objects across the Earth's surface for billions of years. Bejan also points out that rolling stones evolve to have less friction so that they can travel further. That is, they become rounder over time.

"All vehicles—both animate and inanimate—subscribe to the same rules of lifespan and life travel," said Bejan. "I've previously shown this is true for everything from river basins to plumes of smoke. But if that wasn't thinking 'outside of the biology box' enough, these are things even simpler and much more obvious that exhibit the same size effect."

In his previous work on animal size, lifespan and travel distance, Bejan also demonstrated that, despite their differences, all animals should have roughly the same number of breaths per lifetime. In much the same way, Bejan shows in his new work that, all other things being equal, all rolling stones and eddies have the same number of revolutions before their energy dissipates through friction.

"These three characteristics—life span, life travel and the constancy of the number of breaths or revolutions of bodies that move mass—unite the animal, the eddy and the rolling stone," said Bejan. "Traditional camps believe that evolution is only biological and has already been explained to the hilt. I'm showing that evolution is actually based in physics and that it is simply design change over time. To the origin of life in non-living matter, abiogenesis, rolling stones and turbulence add the physics of evolution."

More information: Adrian Bejan. Rolling stones and turbulent eddies: why the bigger live longer and travel farther, *Scientific Reports* (2016).

DOI: 10.1038/srep21445

Provided by Duke University

Citation: Rolling stones, turbulence connect evolution to physics (2016, February 17) retrieved 3 July 2024 from https://phys.org/news/2016-02-stones-turbulence-evolution-physics.html

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