Helping Marvel superheroes to breathe

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Marvel comics superheroes Ant-Man and the Wasp—nom de guerre stars of the eponymous 2018 film—possess the ability to temporarily shrink down to the size of insects, while retaining the mass and strength of their normal human bodies. But a new study suggests that, when bug-sized, Ant-Man and the Wasp would face serious challenges, including oxygen deprivation.

Those challenges, along with their solution-microfluidic technologies, will be described by engineering mechanics graduate student Max Mikel-Stites of Virginia Tech at the American Physical Society's Division of Fluid Dynamics 71st Annual Meeting, which will take place Nov. 18-20 at the Georgia World Congress Center in Atlanta, Georgia.

Mikel-Stites and his advisor, Anne Staples, an associate professor in the biomedical engineering and mechanics department at Virginia Tech, normally study biological fluid dynamics, with a particular focus on insect respiration and insect-scale fluid flows. Staples' lab has developed microfluidic devices inspired by insect respiratory systems in which the flow rate and direction of flow through individual channels in the device can be controlled without the use of valves.

The work, which will be discussed in a separate presentation at the DFD meeting, could reduce the actuation machinery needed for microfluidic devices used in many different scientific fields, and make them more portable and cost-efficient. "Applying that perspective to Ant-Man and the Wasp seemed like a straightforward thing to do," said Mikel-Stites.

In their analysis, the researchers determined that the atmospheric density—basically, the number of molecules (say, of oxygen) in a given volume of air—experienced by the bug-sized heroes is reduced to a level nearly identical to that of Mt. Everest's so-called "death zone," where there is not enough oxygen for a human to breathe. "While the actual atmospheric density is the same for an insect and a human, the subjective atmospheric density experienced by a human who shrinks to insect size changes," Mikel-Stites explained. "For example, a normal-sized person taking a deep breath can expect to inhale some number of oxygen molecules. However, when that person is shrunk down to the size of an ant, despite still needing the same number of oxygen molecules, far fewer are available in a single breath of air.

The "death zone" begins for a normal-sized human about 8,000 meters above sea level. The shrunken superheroes, the researchers calculated, would feel like they were at an altitude of 7,998 meters, and that would make for a serious—if not deadly—case of altitude sickness.

"For someone not acclimated, symptoms of altitude sickness range from headache and dizziness to the buildup of fluid in the lungs and brain, and possibly death. This occurs in part because people may respond by trying to breathe more rapidly, to increase their oxygen intake, and because the body is attempting to function with less oxygen than it normally does," he said.

And that's not the extent of Ant-Man's and the Wasp's problems, the team found. Based on a relationship known as Kleiber's law, which correlates the metabolic rate of an animal to its size, the researchers found that the metabolic rates per unit mass of the superheroes at bug size would increase by approximately two orders of magnitude—as would their oxygen demands.

But all is not lost—thanks to science. According to Mikel-Stites, the use of microfluidic components such as Knudsen pumps (which are driven by temperature gradients) and microscale gas compressors, could be embedded into the helmets of Ant-Man and the Wasp to help them breathe at the microscale.

More information: Presentation E19.3, "Why Ant-Man and the Wasp Need Helmets to Breathe" by Maxwell Mikel-Stites and Anne Staples, will be Sunday, Nov. 18, 5:36 p.m. in Room B306 of the Georgia World Congress Center in Atlanta. Abstract: http://meetings.aps.org/Meeting/DFD18/Session/E19.3

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