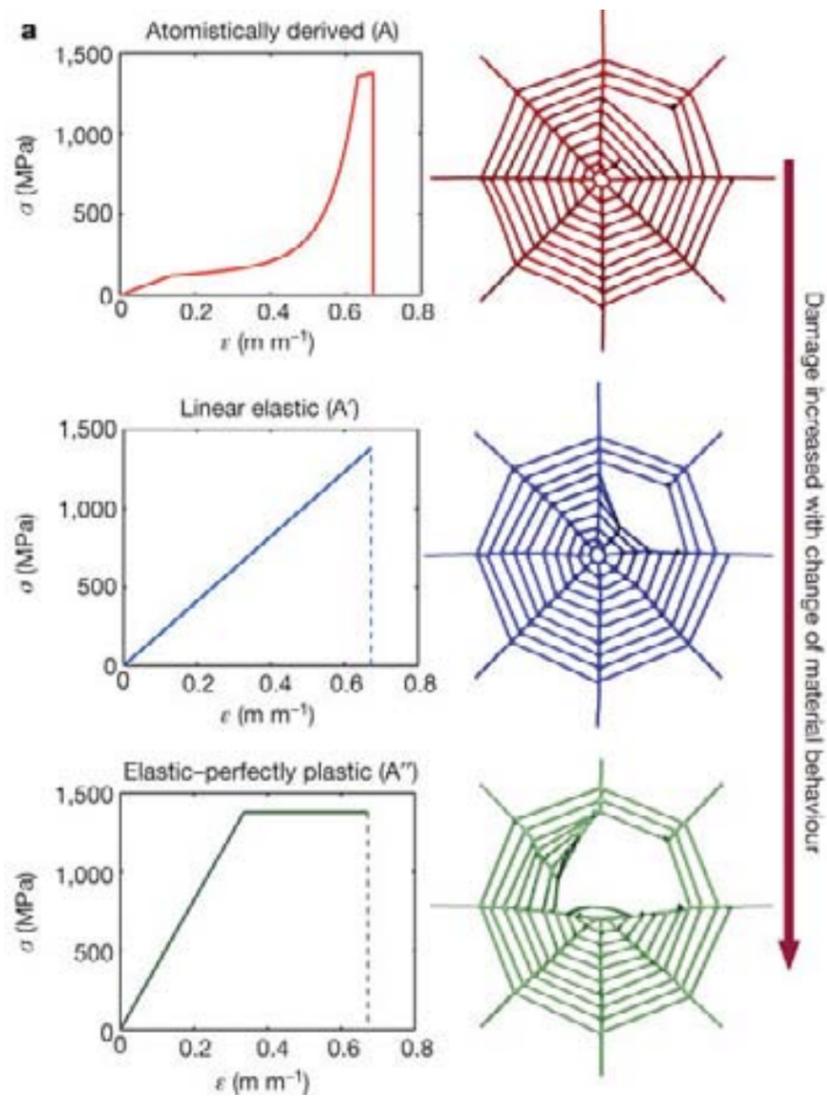


Spider Web Deformation

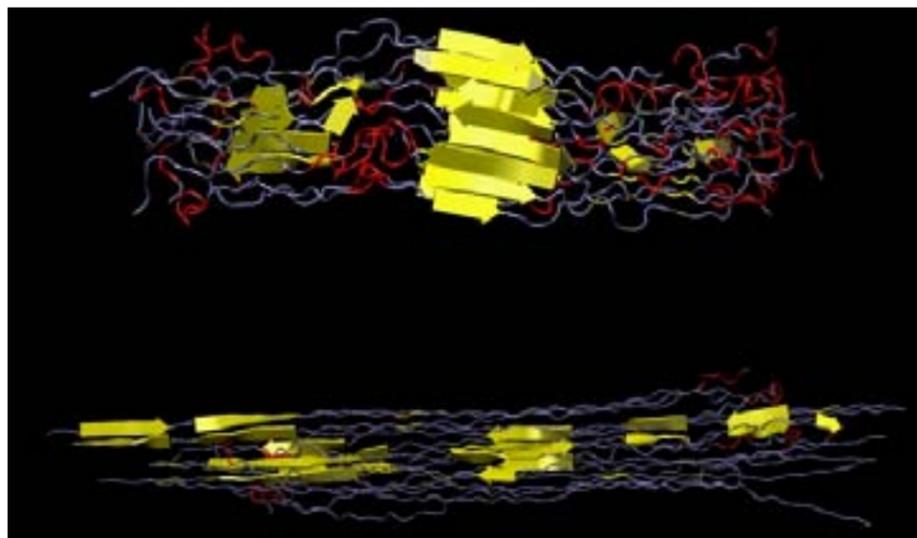
Spiderwebs are one of nature's most fascinating phenomena. When measured pound for pound, the spider silk itself is stronger than steel. However, it is not this strength alone that defines the longevity and durability of the spiderweb. "It turns out that a key property of spider silk that helps make webs robust is something previously considered a weakness: the way it can stretch and soften at first when pulled, and then stiffen again as the force of the pulling increases." For example, let's examine the orb web of the common Garden Spider, or *Araneus diadematus*. If a bug flies into the web and starts flailing around, attempting to escape, it will not destroy the entire web. Instead, only the strand that was in contact with the bug will be broken due to the nonlinear way the web interacts with the force of a bug pulling on that single strand.





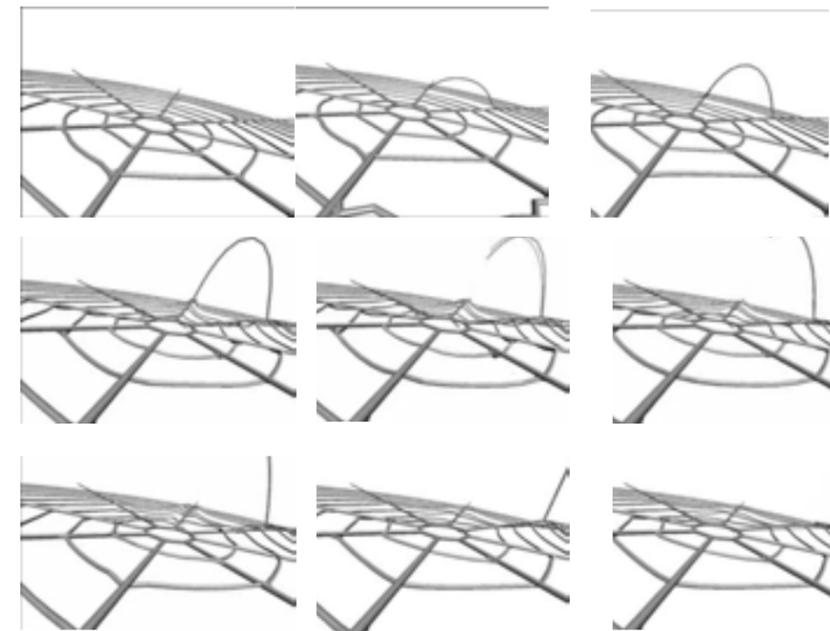
The way that the spider web reacts to an applied force is, in a way, sacrificial. The stress due to the bug pulling on the web is localized, causing only the area directly affected by the force to be damaged. This is due to the versatility of the spider silk in its nonlinear behavior (with nonlinear meaning it changes its behavior over time as the applied force increases). The silk maintains the perfect amount of stretchiness with the ability to stiffen again under stress. If its elasticity were to become linear or perfectly-plastic, the area of damage would increase sixfold.

A diagram and graph depicting what happens when the elasticity of spider silk is tampered with. Reprinted by permission from Macmillan Publishers Ltd: *Nature*. Source: Fig. 2a in Cranford, Steven W., Anna Tarakanova, Nicola M. Pugno, et al. "Nonlinear material behaviour of spider silk yields robust webs." *Nature* 482 (February 2012): 72-76. © 2012.



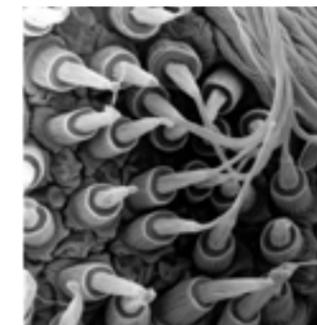
Spider silk proteins in their natural state (top) and when under stress (bottom).

Courtesy of Steven Cranford and Markus J. Buehler. Used with permission. Source: Cranford, Steven W., Anna Tarakanova, Nicola M. Pugno, et al. "Nonlinear material behaviour of spider silk yields robust webs." *Nature* 482 (Feb 2012): 72-76.

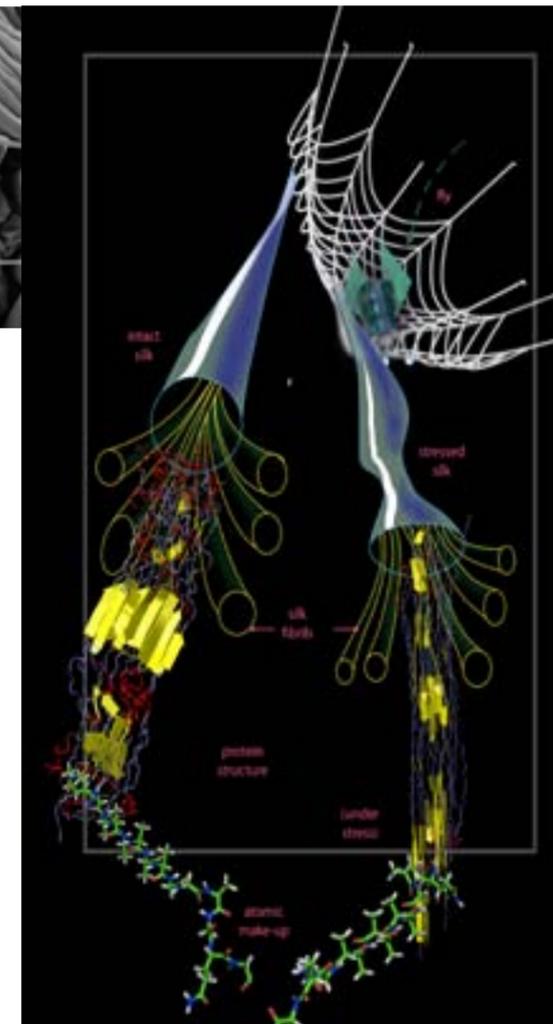


A video simulation of a silk strand within a spiderweb being pulled.

Courtesy of Steven Cranford and Markus J. Buehler. Used with permission. Source: Cranford, Steven W., Anna Tarakanova, Nicola M. Pugno, et al. "Nonlinear material behaviour of spider silk yields robust webs." *Nature* 482 (Feb 2012): 72-76.



An Electron Microscope image of a spider's silk spicgots. Courtesy of Tina Carvalho. Used with permission.



A hierarchical depiction of how a spider web responds to stress.

This image is by Zina Deretsky, National Science Foundation and is in the public domain.

At impact, there is an initial response of deformation throughout the entire web. Then the load is transferred only the silk threads that are in direct contact with the force. These particular threads stretch and soften, allowing the bug to pull the thread out of the plane of the rest of the web. As the bug continues to try and pull away from the sticky silk thread, it adds additional stress to the stick silk strand. Instead of the stress being transferred to the rest of the web, it is transferred to "tiny protein crystals acting as stress points on the targeted strand." This single strand stiffens, and as the bug continues to pull away the crystals deform and the strand breaks.

The web remains intact and functional after this whole endeavor. In fact, after a few broken strands, the web as a whole actually strengthens. The spider can then repair the web instead of having to rebuild it every time the wind blows an object into it or something gets caught and escapes. Silk production is taxing for the spider and it would not physically have enough energy to constantly rebuild its web from scratch throughout the day.

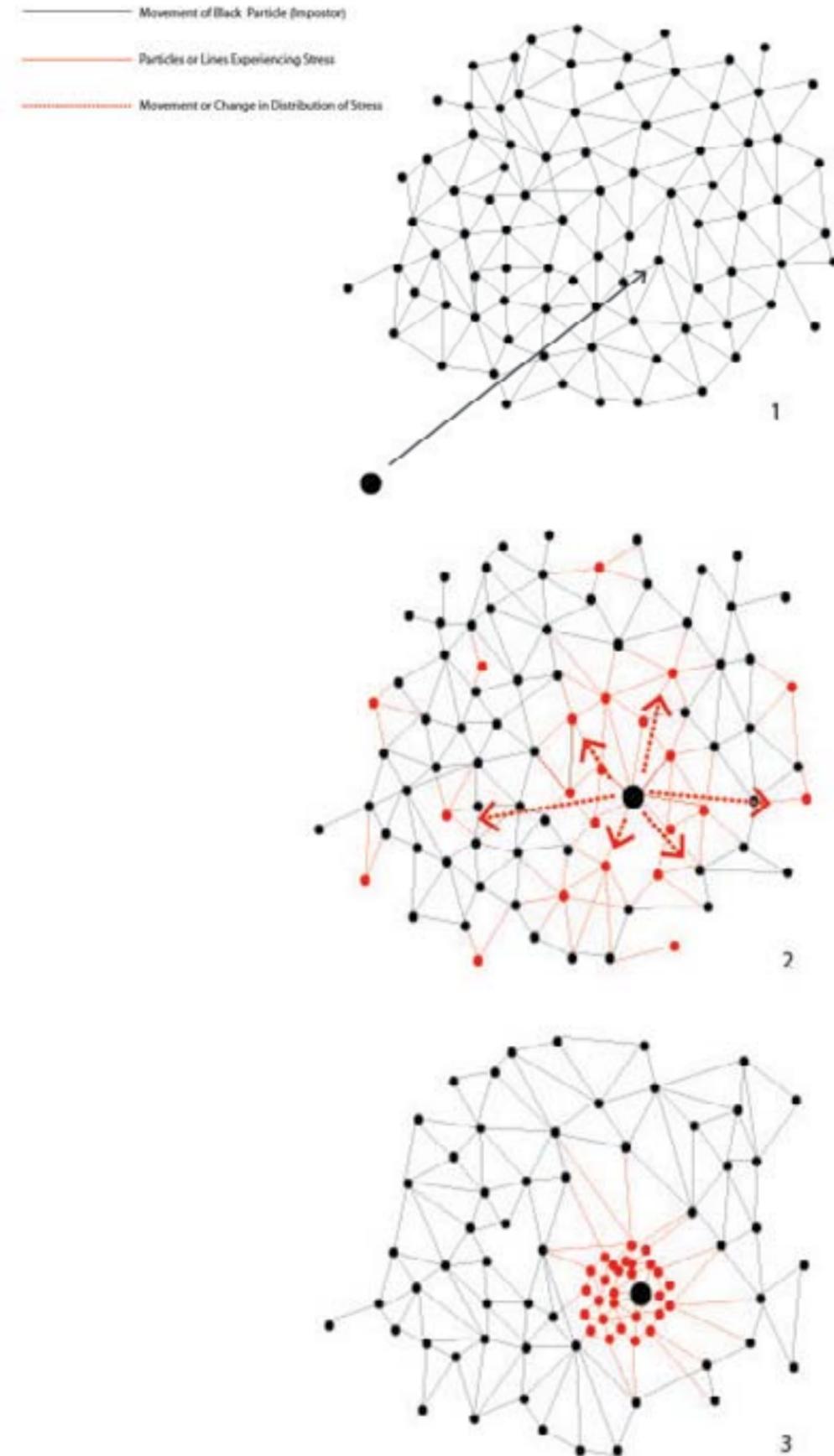
“It is stunning because, in fact, engineered structures don’t behave that way. If a building, a car, or an aeroplane is exposed to large mechanical stress, it typically breaks as a whole and the entire structure becomes dysfunctional...A new design might allow [a] building to flex up to a point, but then certain specific structural elements could break first, allowing the rest of the structure to survive...”

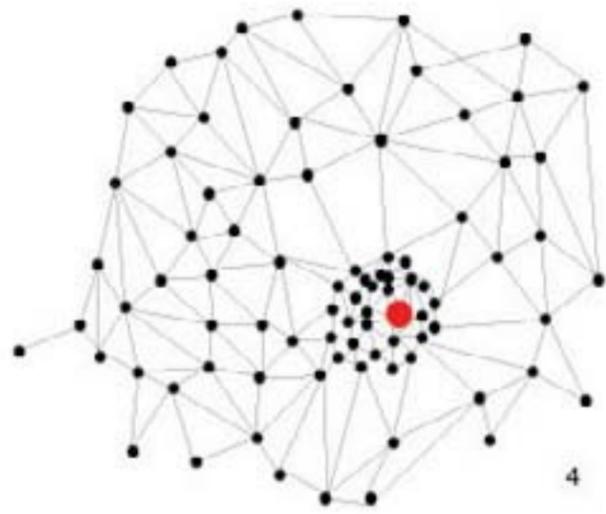
-Dr. Markus Buehler



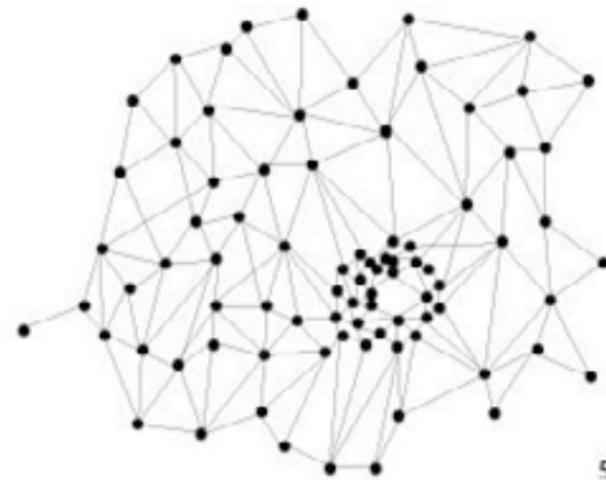
Photo courtesy of [fir0002](#) on Wikimedia Commons.

Photograph of spider web removed due to copyright restrictions.





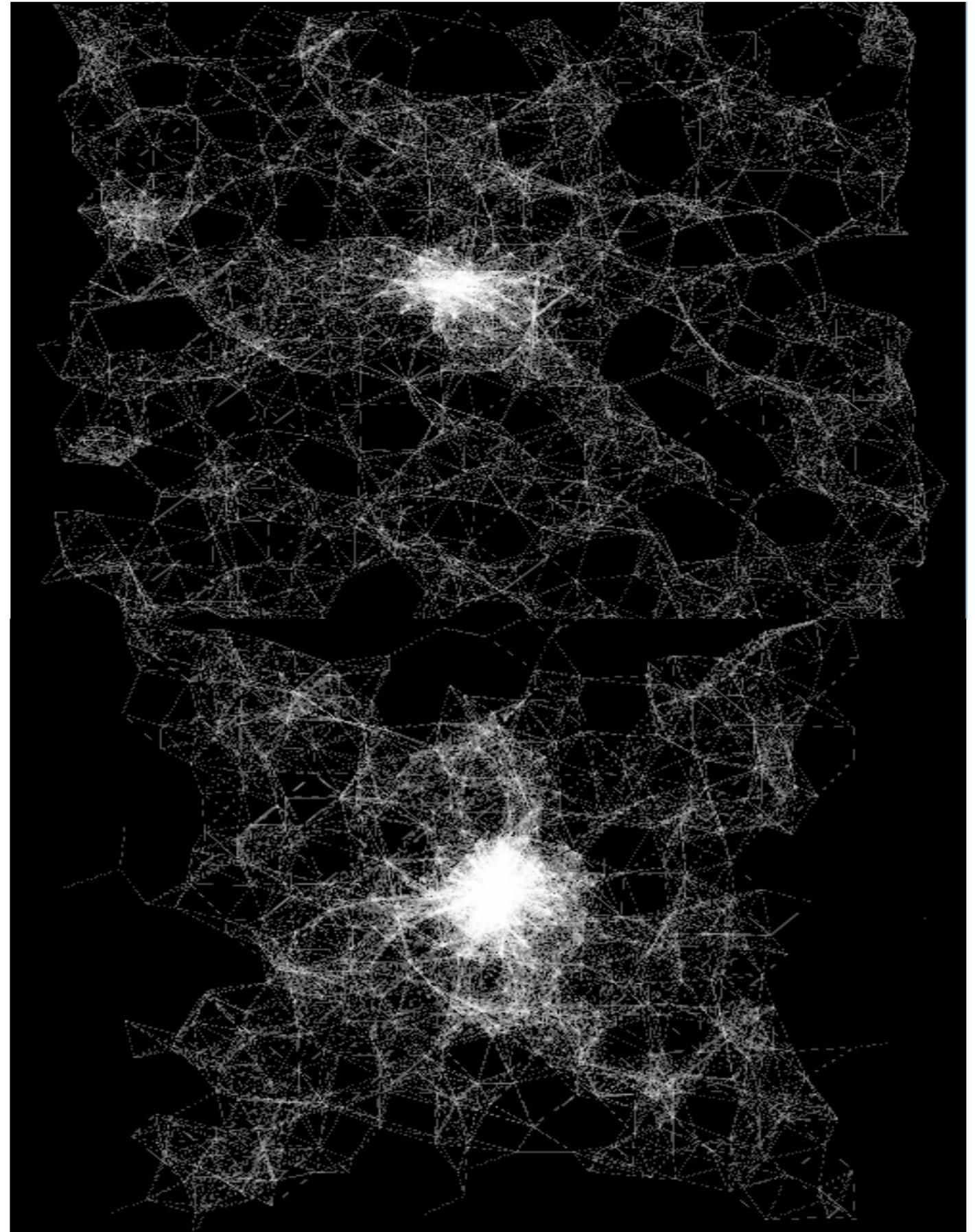
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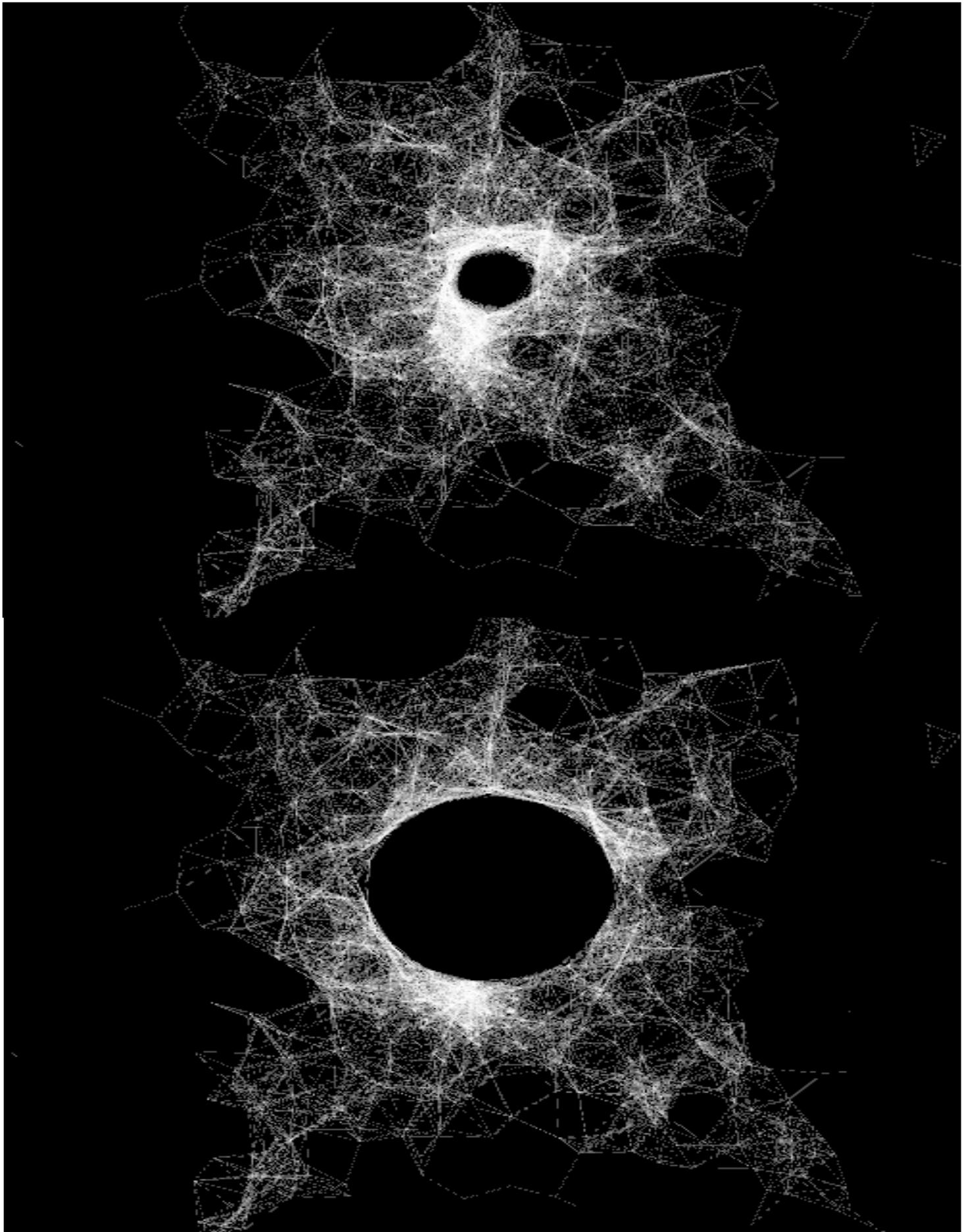
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6



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