UNIVERSITÉ DE GENÈVE

PRESS RELEASE

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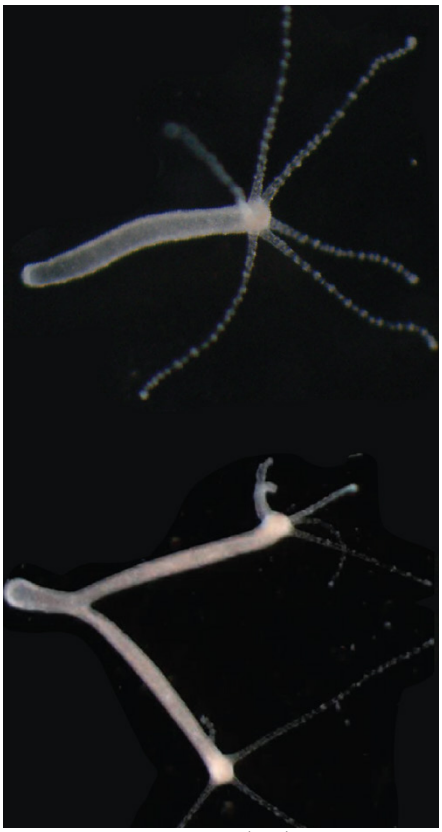
The two-headed Hydra is not just a myth

A UNIGE team has demonstrated how a Hydra can generate two heads when pressure is applied to its body.

The Hydra is a small aquatic species found in freshwater ponds and lakes. This animal fascinates scientists because of its ability to regenerate its head or foot when they are cut off. However, unlike its mythological cousin, it has only one head. A team from the University of Geneva (UNIGE) has demonstrated that it is possible to produce a two-headed Hydra simply by applying pressure to its body after cutting off its head. With a similar method, the team also shows how to produce donut-shaped tissues. This study demonstrates how external mechanical constraints can modify the body's symmetry points and influence its development. These symmetries, present in other more complex animal species, could play an important role in evolution. The full study is available in *Science Advances*.



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A one-headed Hydra (top) and a two-headed Hydra (bottom), obtained after applying gentle pressure along its severed body.

High resolution pictures

Video 1 Video 2 Video 3

In Greek mythology, the Hydra is a nine-headed monster slain by Heracles, each of whose heads grows back as soon as it is cut off. Discovered in the 18th century, Hydra is also the name given to a small aquatic creature from the jellyfish family, living in the calm fresh waters of lakes and ponds. Measuring just a few millimeters, it has one foot and a head equipped with thin tentacles. Its extraordinary regenerative powers earned it the name of its mythological namesake.

When a Hydra is cut perpendicular to the body axis (between the foot and the head), it regenerates to form a new head. By gently compressing the tissue regenerating the head, a team led by Aurélien Roux, professor in the Department of biochemistry in the School of chemistry and biochemistry at UNIGE Faculty of science, has succeeded in mechanically inducing the formation of viable two-headed Hydra. A phenomenon that had never been observed before.

Topological defects

"Inside the Hydra, actin filaments are arranged in parallel along the foot-head axis and converge at the head to form a 'topological defect' in the actin network," explains Yamini Ravichandran, a postdoctoral fellow in Aurélien Roux's team and first author of the study. "Our work shows that these topological defects in the actin order play a central role in head regeneration, acting as mechanical organizers."

By applying gentle pressure along the Hydra's severed body using an agar gel for four days, the scientists induced two topological defects, leading to the formation of two heads. To test whether one defect creates one head, researchers intended to remove the defects and see if the animal could still regenerate. However, there is a difficult constraint to overcome, which is topology. Parallel lines on a sphere always create two defects, the poles of the sphere. To remove the defects, pressure parallel to the actin filaments causes these defects to fuse and disappear, forming a "donut" tissue unable to regenerate a head and eventually starve to death. The topology of the donut is unique as it is the only one that can accept no defects and a structure absent in animal biology.

Hydra is a valuable model because of its easily observable actin network, but the results obtained are applicable far beyond this species. So far, how cells and tissues coordinate forces that shape organisms is not well understood. The proposed concept is that the genetics determine the cell fates, which in turn dictates the forces that shape the tissue. This study shows that genetic factors and tissue mechanics are coupled - and thus acting at the same level - to form a proper head in Hydra. As Aurélien Roux points out, "these results offer novel insights into the mechanical signals that guide tissue repair and regeneration, with potential implications for understanding morphogenesis in other organisms".

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