PRESS RELEASE

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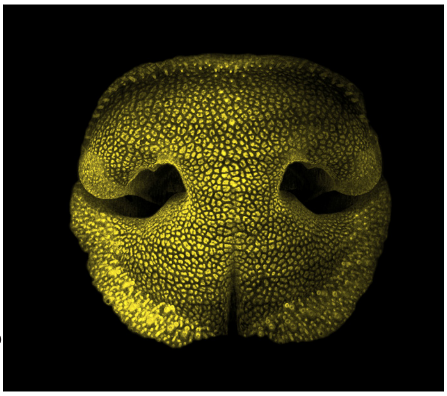
Geometric mechanics shape the dog's nose

A UNIGE team has discovered the physical properties that generate the grooves found on the noses of many mammals.



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Volumetric imaging of an embryonic dog nose, obtained with light-sheet fluorescence microscopy.

Pictures

The noses of many mammals, such as dogs, ferrets and cows, feature grooves forming a multitude of polygons. A team from the University of Geneva (UNIGE) has analyzed in detail how these patterns form in the embryo using 3D imaging techniques and computer simulations. The researchers discovered that differential growth of the skin tissue layers leads to the formation of domes, which are mechanically supported by the underlying blood vessels. This work describes for the first time this morphogenetic process, which could help explain the formation of other biological structures associated with blood vessels. These findings are published in the journal *Current Biology*.

The living world is full of remarkable shapes, some of which can be identified by their patterns of coloration or 3D motifs. Zebras and cheetahs, for example, can be recognized by their skin stripes or spots, while pine cones are characterized by their spiral organisation. These fascinating patterns are generated by various morphogenetic processes, i.e. the generation of shapes during embryonic development.

On the one hand, self-organisational morphogenesis can be mediated by chemical reactions, as described by Alan Turing's reaction-diffusion model, where chemical substances diffuse and interact to create relatively regular patterns, such as the stripes or spots on the skin of mammals and reptiles. On the other hand, some shapes are the result of mechanical constraints. The human brain's convolutions, for example, are produced by a process of differential growth: the cortex forms folds because it grows faster than the deeper layer to which it is attached.

The diversity of life

Michel Milinkovitch's group, professor in the Department of Genetics and Evolution at the UNIGE Faculty of Science, investigates the evolution of the developmental mechanisms producing the complexity and diversity of life. "Finding specific examples of beautiful patterns in living organisms is easy. All we have to do is look around us! Our latest study focuses on the noses of dogs, ferrets and cows, which exhibit a singular network of polygonal structures," explains Michel Milinkovitch.

Indeed, the naked skin of the rhinarium (nose) of many mammalian species features a network of polygons formed by grooves in the skin. By retaining moisture, these grooves keep the nose wet and, among other functions, facilitate the collection of pheromones and odorant molecules. The Geneva-based team collaborated with the Université Paris-Saclay, the École Nationale Vétérinaire d'Alfort (EnvA) and the Institute of Neurosciences de San Juan de Alicante for the collection of rhinarium samples from dog, cow and ferret embryos.

Nose 3D visualization

These samples were observed using "light sheet fluorescence microscopy", a technique that enables the visualization of biological structures in three dimensions. In all three mammalian species, the researchers found that polygonal networks of folds in the epidermis - the outer layer of the skin - appear during embryogenesis, and are systematically and exactly superimposed over an underlying network of rigid blood vessels located in the dermis - the deeper layer of the skin. They also observed that epidermal cells proliferate faster than dermal cells.

Blood vessels form "architectural pillars"

Using these data, the scientists developed a mathematical model and performed computer simulations of tissue growth. This model takes into account the difference in growth rates between the dermis and the epidermis, their respective stiffnesses and, most importantly, the presence of blood vessels in the dermis. "Our numerical simulations show that the mechanical stress generated by excessive epidermal growth is concentrated at the positions of the underlying vessels, which form rigid support points. The epidermal layers are then pushed outwards, forming domes - akin to arches rising against stiff pillars," explains Paule Dagenais, post-doctoral fellow in the Department of Genetics and Evolution at UNIGE's Faculty of Science, and first author of the study.

These results show that, in the case of rhinaria, the position of the polygonal structures of the epidermis is imposed by the position of the rigid blood vessels of the dermis, which exert local constraints during epidermal growth, leading to the formation of grooves and domes at precise locations. "This is the first time that this mechanism, which we call 'mechanical positional information', has been described to explain the formation of structures during embryonic development. But we are confident that it will help explain the formation of other biological structures associated to the presence of blood vessels," concludes Michel Milinkovitch.

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