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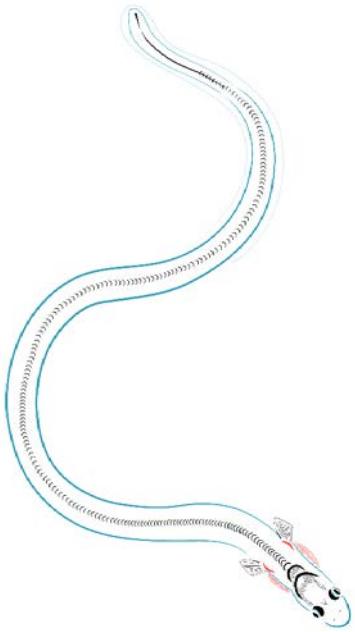
Glass eels use their compass to form a “magnetic memory” of currents

The European eel (*Anguilla anguilla*) migrates thousands of kilometers across the Atlantic Ocean; one of the longest and most challenging migrations undertaken by any animal. Eels hatch in the Sargasso Sea, far from the American and Bahamian coasts. As few-millimeter long, these leaf-shaped leptocephalus larvae drift with the Gulf Stream across the Atlantic until they reach the margin of the continental slope of Europe. Here, leptocephali transform into completely transparent snake-like “glass” eels, which are a few centimeters long. Glass eels then swim over the continental shelf until they reach the coast, where some of them recruit to estuaries and start their migration inland into fresh water. There, eels grow to the yellow eel stage first and, after some years (sometimes 50 years or more), eventually into silver eels, which then undertake the long journey back to the Sargasso, where they spawn and then die.



Glass eel - artwork by A.Cresci

Researchers have been studying the migration of European eels for more than a century, but many questions remain unanswered, especially about the young phases of their life. How do glass eels recruit to the coast? How do they find their way from seawater to fresh water across estuaries? Estuarian environments are often murky, the salinity and temperature are highly variable, and the currents are fast. They are subjected to the constant forcing of the tides, which alternate between ebbing and flooding currents that flow in opposite directions. How can glass eels navigate through such a “crazy” environment?

To shed light on the migration of glass eels, a team of scientists at the Norwegian Institute of Marine Research's Austevoll Research Station, in collaboration with the Physical-Biological Interactions Laboratory at the University of Miami's Rosenstiel School of Marine and Atmospheric Science, explored the possibility that glass eels could use the magnetic field of the Earth to navigate through the estuaries where they recruit.

Just two years ago, the same team of scientists discovered that glass eels can detect where the North and the South are using the magnetic field of the Earth, and that they change magnetic direction when the tidal phase switches. In other words: they have a magnetic compass. However, whether the magnetic direction of glass eels is innate or imprinted during migration was unknown, until now. In their latest research "Glass eels (*Anguilla anguilla*) imprint the magnetic direction of tidal currents from the juvenile estuaries", published in the *Nature* journal *Communications Biology*, the team found that the magnetic orientation abilities of glass eels are even more amazing. The study shows that the direction followed by the glass eels is based on a "magnetic imprinting" of the direction of tidal flows at their estuary: glass eels form and retain a memory of the magnetic direction of tidal currents and use it to migrate through estuaries.

The research team collected glass eels from estuaries in the archipelago of Austevoll, Norway, selecting estuaries flowing towards different directions: North, South, Southeast or Northwest. Eels were then observed in a unique magnetoreception test facility (the "MagLab"), equipped with electric coils - made from kilometers of wire - surrounding a tank. The coils are used to change the direction and intensity of the Earth's magnetic field. In this study, the magnetic field to which glass eels were exposed was rotated such that the N-S and E-W axes were shifted by 90 degrees for each of the glass eels tested.

"If glass eels had imprinted their tidal-dependent magnetic direction at the estuary where they recruit, they would display an orientation direction that varied according to the direction of the estuary" said Alessandro Cresci, Ph.D. student at the University of Miami and first author of the article. Eels were tested in the MagLab, in the absence of water flow or any other external cue other than the magnetic field. "We employed a high level of randomization, as eels came from 4 estuaries flowing in different directions, with 180° differences in the direction of ebbing and flooding tides, and we also rotated the magnetic field for each individual glass eel". Incredibly, glass eels oriented towards the magnetic direction of the tidal current that was occurring at that moment in the estuary from which they were collected. In other words, they remembered the "magnetic upstream" and swam towards it.

"I almost couldn't believe it!" Cresci says. Glass eels not only have a compass, but they use it, together with an internal tidal-clock, to imprint a memory of the direction of the tide, and orient accordingly, even if they are displaced from the estuary. "Glass eels are the superheroes of animal navigation!" Cresci concludes.

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