Abstractions


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The boundary between Earth's molten iron core and the solid mantle is the place to look for clues to how heat from the core is convected to the surface, says geophysicist Patrick Cordier. He and his colleagues at the University of Lille in Villeneuve d'Ascq, France, want to find out what is happening in the D'' layer just above the core–mantle boundary, where temperature and density are dramatically higher than in the rest of the mantle. On page 68 they report the use of quantum mechanics to model how flow occurs in a solid in these conditions.

What is the biggest misconception about the mantle?

That it is liquid. The mantle is rock. The lower mantle is quite homogeneous and dull — until you get to the D'' layer, where seismic waves reveal properties that differ according to the direction of measurement.

Why is the D'' layer the most important?

The density of the molten iron core is double that of the solid mantle, a bigger jump than between the surface of Earth and the air. The core is also immensely hot — around 5,000–6,000 K. Some hypotheses suggest that the mantle may be melting in this layer or maybe that subducted plates stop there. Two years ago, scientists found a new phase transformation in the mantle — from perovskite to a post-perovskite found only at high pressures — which may help explain what is happening in the D'' layer.

Why is this boundary so difficult to model?

Flow of a solid implies the motion of a large number of crystal defects, or dislocations, involving several thousand atoms. This is very complicated to describe quantitatively at the atomic scale. The best tool is quantum mechanics, but in practice modelling even simple materials is difficult. And here we're dealing with an inaccessible mineral under extreme temperature and pressure.

How does your model improve on past efforts?

At this scale, matter behaves like a continuous medium. There's only a thin layer of atoms close to the core of the defect for which we need quantum mechanics. The problem was to link the quantum mechanisms with the bulk of the material.

What insights are now within reach?

My dream is to create a complete numerical model of the deformation of the mantle materials. We've described dislocations, and next we need to describe their behaviour, motion and interactions. The big problem then is to jump from the atomic scale to the grain — and then to the rock. ■

MAKING THE PAPER

Karen Liu

A technique for precisely timed intervention in mouse development.

While completing her graduate work on mouse embryonic development, Karen Liu became frustrated with the limitations in the methodology available to her. She decided that she needed new tools that would enable her to study more precisely the timing of events that occur during embryonic development.

After completing her PhD, Liu joined the laboratory of molecular biologist Gerald Crabtree at Stanford University, under the co-mentorship of craniofacial surgeon Michael Longaker. Combining her mentors' expertise with her own, Liu upgraded her developmental biology toolbox and has used the new tools to prevent cleft palate in a mouse genetic model of the condition (see page 79).

The Crabtree lab had developed an 89-amino-acid tag, called FRB*, which renders any protein fused with it unstable. When the drug rapamycin binds to the tag, however, it stabilizes the protein, restoring its function. Liu decided to use this technique to study development *in vivo*. "I was lucky to have arrived at a time when these tools were available and I could move them in the direction I wanted," she explains.

To test the technique, the Crabtree lab had already constructed mice containing FRB*-tagged glycogen synthase kinase (GSK-3β). This is a component of many important developmental signalling pathways and is involved in several diseases. The researchers had shown that the mice produced an unstable GSK-3β protein. Liu reasoned that the mice would therefore have a similar phenotype as conventional 'knockout' mice lacking GSK-3β. To test this hypothesis she first looked at GSK-3β knockouts and found that these mice were born with defective fusion of the palate (cleft palate) and of the sternum, or breastbone. Exactly the same defects appeared in her FRB*–GSKβ mice without rapamycin, confirming that the tagged GSK-3β was not functional.

The final test came when Liu and her colleagues gave rapamycin injections to pregnant mice carrying rapamycin-responsive mutant embryos. The mutant fetuses developed with a normal palate. "I thought we did not have any mutants in the litter," says Liu. But genetic analysis revealed that the newborn mice did indeed carry the mutant GSK-3β. "I did not believe it," she laughs. "We repeated the genotyping and then repeated the experiment several times."

Rapamycin given at an early stage of development prevented cleft palate; at a later stage it prevented the defect in the sternum. This indicated two distinct windows of time when GSK-3β is needed in development.

"The concept of using a small molecule such as rapamycin to correct a birth defect is something I could have only dreamed of 20 years ago," says Longaker, who is a co-author on the paper. This experiment is, however, a long way away from thinking about a similar approach to therapy, he cautions.

"We were not sure it would work," says Liu. "It was not clear we could deliver the drug to mice, let alone pregnant ones." Having a team of scientists with diverse backgrounds helped make the study possible, says Longaker. "It would have been hard to do in any one lab," he says. "An interdisciplinary team needs a champion and Karen was the glue that kept the project together."

Liu has just set up her own laboratory at King's College in London and plans to continue with the project and refine the FRB* tag system. She plans to develop different combinations of tags and drugs and also to create mice with tissue-specific mutations that can be 'rescued' using this system. ■

KEY POSTDOCS

A study that shows how individual neurons affect zebrafish movement represents the power of technology to advance neuroscience. The collaboration that made the findings possible reflects the advantages of nurturing postdocs and collaborating with them once they have moved on.

Two former postdocs in Joseph Fetcho's Cornell University neuroscience lab developed key techniques to make the study possible. Shin-ichi Higashijimima, now at the National Institute of Natural Sciences in Okazaki, Japan, made some of the first transgenic zebrafish and used fluorescent labelling of individual neurons that observers could watch in real time in the transparent fish. Melina Hale, now at the University of Chicago, refined the use of lasers to knock out individual neurons and was assisted by postdoc Jingyi Fan.

David McLean, a current postdoc in Fetcho's lab, used the cutting-edge techniques to make the discovery that neurons in the lower part of the spinal cord help the fish swim slowly, whereas neurons higher up in the spinal cord enable faster movement (see page 71).

"I am fortunate to have had terrific postdocs who are each expert in different experimental techniques," Fetcho says. We are friends as well, so the collaborations are enjoyable." ■