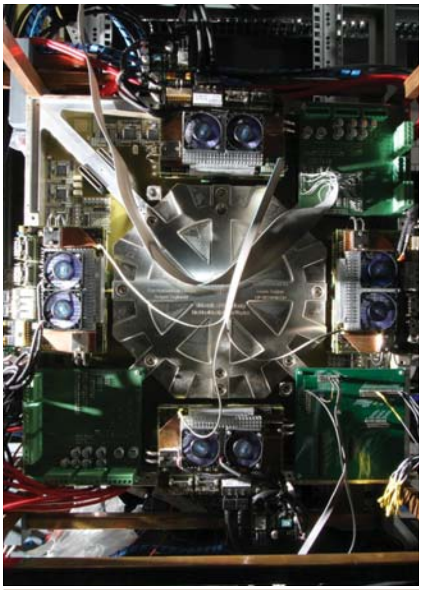
which collaborated on the model, says, "It's a high-resolution scaffold that allows you to assemble data from other scales—genetic, metabolic, neurochemical, . . ."

Karlheinz Meier, a physicist at Heidelberg University and one of three HBP directors, builds neuromorphic computers (see the photo at right). "Rather than simulating circuits from differential equations, we use microelectronics to build physical copies of brain cells, connections, and synapses." Analog circuits use about 100 picojoules for a synaptic signal, compared with 1 J for a supercomputer simulation and 1 fJ for a biological system, says Meier. And whereas supercomputers are up to 1000 times slower than live systems, neuromorphic computers are actually faster—thanks to their even tinier components. "A day's [brain] activity can be compressed into 10 seconds," he says. "This leads to really interesting experiments, for example, on synaptic plasticity and learning." The silicon neurons in the Heidelberg lab's neuromorphic brain each have 20 variable parameters. "Some neurons fire once, some regularly, some in bursts. Some adapt to stimulus and then adjust. We can emulate all of those patterns."



HEIDELBERG UNIVERSITY

This neuromorphic computing system in Heidelberg mimics 200 000 neurons and 50 million synapses on a silicon wafer located behind the central octagonal aluminum plate. Field-programmable gate arrays configure the network and send and read input and output data.

Seductive and polarizing

The HBP has stirred controversy among scientists, with many saying it promises too much. They ask, How can one simulate the brain when so little is known about it? A neuroscientist who requested anonymity says that Markram "makes gorgeous images and hypnotizes the crowd. When I heard him talk, part of me was saying, 'I will follow him to the end of Earth.' The other part of my brain was saying, 'That is nonsense.' It was extraordinary. I was surprised how powerful the seduction was."

Supporters of the HBP dismiss the criticism. McGill's Evans blames the media and funding agencies for the hype around the European project. "You cannot get the public's and politicians' attention unless you make a big pitch," he says. "It doesn't matter if the project does not reach its ultimate goal of simulating the entire human brain. Much good science will come out of it." As to simulations being premature, Lippert says, "Simulations constrain experimental research. Not simulating would exclude an important approach to science. The promise is only to increase the understanding of the brain."

For his part, Meier says, "If everyone is for a project, it's probably not that interesting. If everyone is against it, it's probably wrong. But if it's polarizing, that is a good sign."

Big data, big implications

Scientists in the US and Europe see the two big brain projects as complementary. The techniques developed in the BRAIN Initiative will be used to gather new data, which, in turn, will feed into the simulations of the HBP.

But the masses of data "that will come gushing out from all those labs" are a "potential showstopper," says Terry Sejnowski, a neuroscientist at the Salk Institute. "The current state of data storage and analysis will have to be amped up." At the same time, he says, "there will be a major effort to make the data public—as is the norm in astronomy and genomics but not in neuroscience."

An overarching goal is to understand the brain in both health and disease and eventually to help treat such disorders as depression, epilepsy, Alzheimer's and Parkinson's diseases, and autism. "I have two agendas," says Harvard's Wedeen. "One is to understand how the brain works. And we are urgently in need of a revolution in mental health."

Beyond leading to treatments for disease, the brain projects "will galvanize industry," says the Kavli Foundation's Chun, pointing to robotics as one area likely to benefit from research on the brain. "It's only three pounds of mushy material that, using little energy, can do unbelievable things," she says. "Imagine if we can unlock its secrets."

Toni Feder

Thin, layered materials get fat portfolio in Europe

Solar cells. Water desalination. Dialysis. Sensors. Oil extraction. Those are just some of the potential applications that scientists envision for graphene and related materials. The Graphene Flagship, which kicked off in mid-October, is one of the European Commission's two future and emerging technologies flagship projects—well-funded, decade-long, multidisciplinary efforts with grand ambitions for science and society. (See the story on the other flagship, the Human Brain Project, on page 20.)

Graphene, which consists of a single layer of carbon atoms, is strong, lightweight, flexible, and transparent, and it is a good conductor of heat and electricity. "The challenge is to bring the unique properties from the lab to the marketplace," says Andrea Ferrari, a professor of nanotechnology at the University of Cambridge and chair of the flagship's executive board. "We want to revolutionize multiple industries. We want to create jobs. We want the applications to benefit society." The Graphene Flagship brings together some 125 groups in universities, academic and research institutes, and industry in 17 countries across Europe to coordinate their work on graphene and other layered materials and hybrid systems.

"To bridge the gap from basic research to applications, you need to have expertise in materials production, in making components from those materials, and in integrating components into systems—airplanes, cars, electronics, whatever," says flagship director Jari Kinaret, a condensed-matter theorist at Chalmers University of Technology in Göteborg, Sweden. "In Europe, there is not a single country that can integrate all of this."

The flagship projects are each expected to receive about €1 billion ($1.3 billion) from the European Commission and member states, plus contributions from participating institutions and industries. The exact numbers will be decided in stages. For now, the Graphene Flagship can count on €54 million from the EC through March 2016, when Horizon 2020, Europe's next long-term strategy, goes into effect. "The most important thing," says Kinaret, "is the time period. It's rare to talk about 10-year projects."

Toni Feder