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The Next Frontier Is Inside Your Brain

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The Obama administration is planning a multiyear research effort to produce an "activity map" that would show in unprecedented detail the workings of the human brain, the most complex organ in the body. It is a breathtaking goal at a time when Washington, hobbled by partisan gridlock and deficit worries, seems unable to launch any major new programs.

This effort — if sufficiently financed — could develop new tools and techniques that would lead to a much deeper understanding of how the brain works. The ultimate aim, probably not reachable for decades, is to answer such fundamental questions as how the brain generates thoughts, dreams, memories, perception and consciousness — and to find ways to intervene and influence such brain activities. It may also be possible to determine how the brain changes over time in response to learning.

We are a long way from that kind of understanding today. Scientists using electrodes and existing imaging technologies have been able to study how individual neurons and small networks of neurons respond to stimuli. But the human brain has some 100 billion neurons, each interacting with perhaps 10,000 other neurons through complex circuitry that no existing technology has the speed or resolution to track. All told, there could be 1,000 trillion connections between neurons in the brain.

Scientists have been able to infer the main functions of certain regions of the human brain by studying patients with head injuries, brain tumors and neurological diseases or by measuring oxygen levels and glucose consumption in the brains of healthy people, according to Dr. Francis Collins, director of the National Institutes of Health. But as Dr. Collins explains, this is like listening to the string section alone instead of the entire orchestra.

The sweeping scope of the new initiative, which has not yet been officially unveiled, was revealed by John Markoff in The Times on Monday. Fortunately, there is a strong base of knowledge to build on. Researchers have already made significant discoveries about brain functioning. They have identified how neurons behave at the point where anesthetized patients lose awareness, bringing us a step closer to understanding the nature of consciousness. They have linked certain areas of the brain to musical creativity and other areas to the formation of emotions and habits.

Scientists have even determined what animals are dreaming by first having them walk through certain locations in a fixed order and recording which neurons are activated. Then when the animal is sleeping, they can see if the same neurons are firing in the same order, an indication that the animal is probably dreaming about the walking it had just done. This rather simple experiment involves putting electrodes in the brain to record perhaps 100 neurons at a time. To really understand what is happening when an individual dreams, scientists will need to record what happens to many thousands or possibly millions of neurons as the dream is unfolding.

Recent advances in nanotechnology, microelectronics, optics, data compression and storage, cloud computing, information theory and synthetic biology could help make possible investigations that were unimaginable before. For instance, scientists might extend the value of traditional brain scans by implanting nanosensors, wireless fiber-optic probes or genetically engineered living cells to penetrate brain tissue and report which neurons are firing and when in response to various stimuli.

There should be clinical benefits as well. The knowledge developed could enable biomedical scientists to find more accurate ways to diagnose and treat depression, schizophrenia, dementia, autism, stroke, Parkinson's and other illnesses or injuries of the brain.

President Obama hinted at broad ambitions for scientific advancement in his State of the Union address, saying, "Now is the time to reach a level of research and development not seen since the height of the space race." He mentioned mapping the human brain, but it's more likely that scientists will start with smaller brains and central nervous systems — like those of worms, fruit flies, zebra fish and small mammals — before they move on to primates. No firm budget exists yet, but some leading researchers say this initiative may require more than $300 million a year, or some $3 billion over the first decade, in federal support. Whether that is new money or drawn from existing well-financed programs, it is an investment worth making.

Of the big scientific programs in the past half-century, few if any were as daunting as the brain project. The race with Russia to land men on the Moon in the 1960s was comparatively straightforward because it was largely achieved with technologies that already existed. The Human Genome Project, completed a decade ago, had a clearly defined goal — to identify the complete sequence of genes on every chromosome in the body — and there was little doubt it was achievable; the only question was how fast and at what cost.

By contrast, the brain project will have to create new tools to explore an organ that is the seat of human cognition and behavior. A task of that magnitude can truly capture the imagination.