What is Learning?

Welcome to learning how to learn. My name is Terry Sejnowski. Let me introduce you to your brain!

First, some brain surgery. We take off the skull and take out the brain. This brain weighs three pounds, but it consumes ten times more energy by weight than the rest of the body, a very expensive organ. It is the most complex device in the known universe. All of your thoughts, your hopes, your fears are in the neurons in this brain. We prize our abilities to do chess and math, but it takes years of practice to acquire these skills. And digital computers are much better at it than we are. It came as a surprise to discover that what we do so well and take for granted, like seeing, hearing, reaching, running, are all much more complex problems than we thought and way beyond the capability of the world's fastest digital computers. What this illustrates is that we are not consciously aware of how our brains work.

Brains evolved to help us navigate complex environments, and most of the heavy lifting is done below our level of consciousness. And we don't need to know how it's done in order to survive. Psychologists who study the unconscious mind have found that influences include thought processes, memory, emotions and motivation. We are only aware of a very small fraction of all of the activity in the brain, so we need to rely on brain imaging techniques to guide us.

Here is the activity map of someone's brain who was asked to lie still, at rest, in a brain imaging scanner. On the left is the side view of the brain and on the right is the view from the midline. The colors indicate brain areas whose activities were highly correlated, as shown by the time courses below, color-coded to the brain areas. The blue areas are highly active when the subject interacts with the world, but turn off in a resting state. The red-orange areas are most active in the resting state and are called the default mode network. Other brain areas are also more active when you are resting, and these areas can be further divided into groups of areas that have common patterns of activity. This is a new and intense area of research, and it will take time to sort out all the resting states and their functions.

There are a million billion synapses in your brain where memories are stored. The old view of the brain is that once it matures, the strengths of synapses can be adjusted by learning, but the pattern of connectivity does not change much unless there is brain damage. But now we know that brain connectivity is dynamic and remains so even after it matures. With new optical techniques for imaging single connections between neurons called synapses, we can see constant turnover, with new synapses being formed and others disappearing. This raises a puzzle. In the face of so much turnover, how do memories stay stable over so many years?

This is a picture of one dendritic branch on a neuron which receives inputs from other neurons. The synapses are on the spiny knobs coming off the dendrite. On the top, the dendrite was imaged before learning. The same dendrite is shown below after learning and after sleep. Multiple synapses that are newly formed together on the same branch are indicated by the white arrowheads. You are looking down into the brain of a live animal. This is really a

fantastic new technique. Synapses are less than a micron in diameter. In comparison, a human hair is around 20 microns in diameter. This new technique allows us to see how learning changes the structure of the brain with a resolution that is near the limit of light microscopy.

This illustrates that, intriguingly, that you are not the same person you were after a night's sleep or even a nap. It is if you went to bed with one brain and woke up with an upgrade. This is a better deal than you can get from Microsoft. Shakespeare, the great English poet, already knew this. Here is Macbeth lamenting his insomnia: "Sleep that knits up the raveled sleeve of care, the death of each day's life, sore labor's bath, balm of hurt minds, great nature's second course, cheif nourisher in life's feast." Here, Shakespeare is making an analogy between knitted clothes and sleep that knits up the loose threads of experience and concerns during the day and weaves them into the tapestry of your life story.

You will learn in this first week how to take advantage of your unconscious mind, and also sleep, to make it easier to learn new things and solve problems. During the lectures you may ask yourself, how does the brain do this? A good place to find out more about your brain is the website brainfacts.org, brainfacts, one word, .org (http://www.brainfacts.org/). You will find a wealth of interesting things about brains and behavior, and in particular about learning and memory.

I am Terry Sejnowski. Happy learning until we meet again.