Do you remember your name? Of course you do. What a silly question to ask. But what if you were asked about what you did exactly on this date and at this time one year back? It would be fair to guess that you would not be able to recall your activities. But then you might remember what you did during your sixth birthday to the minutest detail. Doesn’t it ever make you wonder? We can remember some incidents with minute painstaking details while other incidents simply fade with time.

The answer lies in the 1300 grams of matter trapped inside your skull – your brain. The human brain occupies only a mere two per cent of your body weight but is the single most fascinating organ sculpted by evolution in the history of life. Armed with a 100 billion neurons and much more than a staggering quadrillion number of synapses, the brain analyses, interprets, stores and recalls data. More importantly, it decides what it is going to store, like your mobile number and what it is going to just let fade away, like the metabolic cycles you studied yesterday. But how does it do so?

Learning may be described as the mechanism by which new information about the world is acquired, and memory as the mechanism by which that knowledge is retained. Where exactly in the brain does this retaining occur? The answer: in the gap between the neurons, the synapses.

A synapse is a small gap between one terminal of a neuron and the other. When a neuron is stimulated, it generates an electric potential and passes this potential to other surrounding neurons – this moving electrical signal is termed as an ‘action potential’. When the signal in the form of action potential reaches a gap between the neurons, chemical compounds are released into the synapse, which traverses the gap and reaches the...
other neuron, whereupon the electrical signal is generated again.

The chemicals that cross the spatial barrier are termed as ‘neurotransmitters’ and every neurotransmitter released from the pre-synaptic knob has its own interacting partner in the post-synaptic membrane called a ‘receptor’. Interaction with this receptor initiates an action potential in the post-synaptic neuron, which is then directed towards its axon to be passed on to other neurons.

When your sense organs perceive a data, like when you see or hear something, a pathway is created in the brain. This means that neurons involved in memory and learning get activated and they fire up through their synapses creating a new neuronal chain. This is what is called a ‘short term memory’, a neuronal pathway that exists only for a few hours. But when you perceive the data multiple times, this pathway is used over and over and is somehow ‘strengthened’.

Imagine you bought a new SIM card. You may not remember the 10-digit number immediately. But with regular use, you master the skill and within a week you are telling others the number as if you had known it your whole life.

One of the most common neurotransmitters associated with learning and memory is the amino acid, glutamate and it acts mainly through

The AMPA receptor is structured such that when glutamate binds, it triggers an influx of sodium ion into the post-synaptic knob. When this influx of sodium reaches a critical threshold, an action potential is triggered via which the impulse is carried forward through the body of the post-synaptic neuron.

On the other hand, upon binding glutamate, the NMDA allows an influx of calcium ions. But there’s a catch here! The sole binding of glutamate does not initiate calcium influx; the receptor needs to be activated via some other mechanism.

A synapse is a small gap between one terminal of a neuron and the other. When a neuron is stimulated, it generates an electric potential and passes this potential to other surrounding neurons – this moving electrical signal is termed as an ‘action potential’.

Schematic diagram of a synapse. Electrical signals travelling down the axon of neuron 1 reach the pre-synaptic knob and initiate neurotransmitter release. The chemicals cross the synapse and reach their corresponding receptors in the post-synaptic knob (neuron 2), which initiates re-generation of the action potential.
two kinds of receptors – the N-methyl-D-aspartate (NMDA, for short) receptor and the alpha-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid (AMPA, for short) receptor.

The AMPA receptor is structured such that when glutamate binds, it triggers an influx of sodium ion into the post-synaptic knob. When this influx of sodium reaches a critical threshold, an action potential is triggered via which the impulse is carried forward through the body of the post-synaptic neuron.

On the other hand, upon binding glutamate, the NMDA allows an influx of calcium ions. But there’s a catch here! The sole binding of glutamate does not initiate calcium influx; the receptor needs to be activated via some other mechanism. This activation is brought about by the influx of sodium ions through some other means. This is where things start becoming interesting.

Let us understand a simplified version of memory formation. Suppose you have started learning a really complicated metabolic cycle. When you read the cycle once or twice, neurons are fired in a certain part of your brain, among them the most significant being the neurons associated with ‘learning’ and ‘memory’, the interaction being mediated by glutamate in the synapses.

Let us consider the movement of the signal through two such neurons in the large connective chain. As the electrical signal passes through the axon and reaches the pre-synaptic membrane, it initiates release of glutamate. The glutamate released diffuses into the synaptic space and reaches the post-synaptic membrane, where it interacts both with the AMPA and NMDA receptors. However, this interaction results in only the AMPA receptor getting activated, allowing sodium ions to enter the terminal portion of the post-synaptic neuron.

The presence of excess sodium ions inside the post-synaptic knob activates the NMDA receptors, which, in the presence of glutamate, initiate calcium influx. This results in the initiation of a number of signalling pathways, i.e., it leads to activation of certain proteins, which in turn activate other neuronal proteins. The signal passes from protein to protein until it culminates in three major changes:

(i) The synthesis and release of the gas nitric oxide. NO, surprisingly, acts as a local messenger in living systems. The NO diffuses out of the post-synaptic membrane and into the pre-synaptic membrane, where it increases glutamate production.

(ii) Increase in AMPA production leading to a higher number of AMPA receptors embedded in the post-synaptic membrane.

(iii) Further structural changes in the two membranes that facilitate faster information transfer.

Imagine a tough subject you have no intention of studying. You open the first page every day, read a few lines and then you decide to shelve it for “later”. Until one fine morning you realize you have one day left before the exam and you start to panic.

Now, as you read the cycle again and again, the same neuronal pathway fires in your brain, repeatedly, producing higher amounts of glutamate and its receptor, AMPA. Continuous firing of the same neuronal pathway keeps on modifying the synapse, making the pathway more and more stable. This is the basis for memory formation and is technically termed as ‘long term potentiation’ or LTP for short.

Where does this phenomenon occur in the brain? Primarily in an area called the hippocampus, which is itself a part of the limbic system. But have you noticed that you do not remember all that you read? In fact, things you do not like tend to be very difficult to memorise. Why is this? If everything is memorized through glutamate pathways, then why do we have selective memory? If you are a fan of sports, you will be able to quote sport statistics with much ease than a phone number or a chemical reaction. This is again due to how we store information.

Once you know how your brain functions in helping you memorise subjects and incidents and details, perhaps you will find it easier to manipulate your brain for your own benefit.
Learning may be described as the mechanism by which new information about the world is acquired, and memory as the mechanism by which that knowledge is retained. Where exactly in the brain does this retaining occur? The answer: in the gap between the neurons, the synapses.

Remember, the human brain does not store information like a computer. The hippocampus which is involved in LTP, is also a part of the limbic system, an area of the brain which deals with emotion. So when you read something which you are fascinated with, or emotionally attracted to, the signals are intensified, thereby reducing the time taken for LTP (quicker long term memory formation). But when you are force-fed something you don’t like, the limbic system remains unaffected and therefore it takes a longer time to create LTP.

Now, in life we have to memorize many things we are not comfortable with. Since they do not evoke a rewarding emotional response, we keep shunning them until the very last moment. Imagine a tough subject you have no intention of studying. You open the first page every day, read a few lines and then you decide to shelve it for “later”. Until one fine morning you realize you have one day left before the exam and you start to panic. You open the chapter and start mugging up the lines without even comprehending its meaning. As a consequence, your exam results suffer.

If this sounds familiar, then you are not alone. Millions of students worldwide face this problem. Is there a solution to the dilemma?

In fact, there are two solutions. The first and foremost is to try getting involved in a subject which you are intrigued by. If you want to be a poet and/or interested in literature, it would be a mistake to try and work through biology. Second, and the most common, even if you have to read something which you are bored by, you can trick the brain into liking it. For example, if you are studying chemistry, try to understand the reaction and find the logic behind the apparently tedious matter before trying to memorize it. Consult your peers, if need be. It is mandatory that you do what it takes to understand the chapter. Once you look through the veil of words and comprehend the true meaning, the emotional centres of your brain will automatically be activated. Understand what you read and you will be able to form LTP easily.

Coming back to the question that we had wondered about in the opening paragraph: why do we remember our names so well but not the exact action performed on a particular date years ago. The answer lies in LTP formation.

So many people have called you by your name and you yourself have written that word so many times, that somewhere in your brain, there exists a permanent pathway corresponding to that word. Anyone utters the word, your pathway is activated and you recognize it to be your name. On the other hand, there are a thousand things you do everyday and not repeat them. These incidents create temporary pathways that are used once and then never used again. The synapses in that pathway are not strengthened and thereby, with time you tend to forget about these incidents.

So, once you know how your brain functions in helping you memorise subjects and incidents and details, perhaps you will find it easier to manipulate your brain for your own benefit.

Mrs. Jayashree Das has been teaching Biochemistry to undergraduate and postgraduate students of Dayananda Sagar College of Biological Science. She is currently Senior Lecturer and HOD-in-charge for Biochemistry in the Dayananda Sagar College, Shavige Malleshwara Hills, Kumarswamy Layout, Bangalore–560078; Email: jayashree_das671@gmail.com