Pharmacology - Neurotransmission

Did you know that everything we do, every feeling we have, every decision we make, and every memory, and every dream that we have involves a process where one cell in our brain is communicating with another? The brain is composed of a number of different cells. And the most important for us in this course are the nerve cells, or neurons.

Neurons are specialised cells that perform two actions. First, they receive information from other neurons, and they modify their own activity accordingly. And secondly, they pass that information on to other neurons, and so continue sending information throughout the brain.

These neurons can process huge amounts of information. The human brain has in the order of 100 billion neurons. And each of these neurons has a unique set of around 10,000 neurons. And we put this together and we've got over a quadrillion neurons connected in some way.

Neurons are connected in the brain in the same sort of way as a road or a telephone line, and sends certain information throughout the brain. These roads, or pathways, tend to specialise in the information that they send and the parts of the brain that they traverse. For example, a part of the brain called the limbic system specialises in emotion.

The pathway of neurons that passes through the limbic region to the frontal cortex is often called the reward pathway. If information travels through the reward pathway, we feel happy and euphoric. And as the pathway connects with the part of the brain where we process information, where we make decisions, and where we lay down new memories, these decisions and memories are given an emotional meaning.

Information that's sent through a neuron is actually an electrical message. And we call this electrical message an action potential. Neurons are not in direct contact with each other. And there's small gap called a synapse between each neuron.

To transmit the message across a synapse, the electrical message is transformed into a chemical message. Communication between neurons occurs across a synapse. And it occurs via a chemical means. Neurons send out chemical messengers, or neurotransmitters, as they're called. And these neurotransmitters influence the activity of the next cell.

The message is sent quickly. And it sends the message to either continue with the message or to slow it down. The action potential travels down the neuron and it triggers the release of a neurotransmitter that's been stored in the neuron terminal. This neurotransmitter, and this process of release of the neurotransmitters, passes information across the synapse and onto the next neuron.
And once there, a number of things can happen. Some of the neurotransmitter can bind to a protein called a receptor and activate it. If a receptor is activated, then it will activate that cell. And by so doing, it passes on the information from one neuron to another.

The chemical bonds between the neurotransmitter and its unique receptor are relatively weak, and they're temporary. Many people imagine this as a process similar to a key and a lock, with receptors acting as the lock while the neurotransmitter, the unique neurotransmitter for that receptor, is acting as the key. If the right key, or neurotransmitter, attaches itself to the right lock, then that neuron will be activated.

Our brains have evolved so that there are many different receptors, each of which are designed to accommodate their own natural neurotransmitter. But drugs, and drugs of abuse, mimic these neurotransmitters. And thus they bond with the receptor, they open the lock.

After activating the receptor, some of the neurotransmitter might be metabolised by enzymes in the synapse and then excreted from the body. But most is then taken back up into the originating cell by a transporter molecule, and it's stored for another time. The important message for us is that drugs of dependence can affect any of these steps in the process of neurotransmission.

So, neurons communicate with each other by neurotransmitters. And these neurotransmitters change the firing rate, up or down, of the connected neuron. Because neurons work in teams, the contributions accumulate quickly, within milliseconds, and a tide of information sweeps across the brain. Every time you think, or feel, or move, or remember, this tide of information is sweeping across your brain.

Now, the influence of one cell on another can go in one of two different directions. You can switch the cell on, excitation, or it can turn it down, it can inhibit it. Glutamate is the primary excitatory neurotransmitter in the brain. It is actually a derivative of sugar. It's associated with long-term changes in the brain, associated with learning and memory. And it's also associated with certain physiological changes.

The other major neurotransmitter we call GABA. And it's the main inhibitory neurotransmitter in the brain. It regulates excitation in the brain. It inhibits the spread of information.

Now, this process of excitation through glutamate and inhibition through GABA can be combined in the most complex of ways. Excitation can build communities of neurons that activate each other. Think of a wave crashing on the seashore, or a chant building at a sporting event.

Inhibition, for example, doesn't just reduce the flow of information, it just makes sure that this wave of information, and that the neurons involved, remain focused, remain limited, and stay focused on the task at hand. Alcohol and benzodiazepines such as Valium enhance the effect of GABA. They slow the transfer of information in the brain.

Drugs contain molecules that can merge with the brain's communication system and disrupt the way that nerve cells normally send, receive, and process information. Some drugs, like cannabis or heroin, have a similar chemical structure to the neurotransmitters naturally produced in the brain. And this similarity allows them to bind to the receptors and activate the nerve cells and send extra strong messages.
Other drugs, like cocaine, ecstasy, or crystal methamphetamine, cause the neurons to release huge amounts of the natural neurotransmitter. They can also prevent them switching off by blocking the process by which they're put back into storage, or metabolised. And so, as a result, the signalling system isn't turned off, and the brain becomes flooded with neurotransmitters.

We can think of two broad ways that drugs can influence the process of information in the brain. The first is by imitating the brain's natural chemical messengers, the neurotransmitters. And the second is by over-stimulating the pleasure zone of the brain, the so-called reward pathway. And so it's to this pleasure zone, this reward pathway, that we now need to turn our attention.