Neuroanatomical basis of addiction

I'm Dr. Claire Troakes. I'm from the brain Bank Institute at the Institute of Psychiatry, King's College, London. And I'm going to talk about the neuroanatomy of addiction.

The human brain is made up of over 100 billion nerve cells, which call neurons. And they have over 100 trillion connections between them. A healthy adult brain would weigh about 1,500 grammes, quite heavy, quite large.

And the brain can be further divided into several regions. So we have the brain stem. This connects the brain to the spinal cord and is responsible for the automatic functions of the brain, things we don't need to consciously think about, that don't stop when they fall asleep—so our heart rate, swallowing, breathing, all those sorts of things.

The cerebellum is located near the back of the brain at the top of that brain stem. And it's involved in balance and coordination of movement. The cerebral cortex is the largest part of the brain, and it's divide it into the left and right hemispheres.

They look all wrinkly. They've got a large surface area packed into them. And each hemisphere can be further divided up into four different lobes.

So far our frontal lobe at the front, it's involved in personality, planning, emotional restraint, higher executive functions, all the sort of higher human functions we might consider. The parietal lobe is involved in visuospatial awareness. And the occipital lobe at the back of the brain is involved in processing of vision. The temporal lobe behind our ears contains the hippocampus, which is our memory centre and also some of our auditory and language areas.

The neuroanatomy of addiction revolves around what's known as the reward pathway within our brain. So neurons release neurotransmitters when they are stimulated. And this leads to feelings of well-being. The reward pathway developed originally to promote survival by rewarding behaviour such as feeding, drinking, seeking shelter, and reproduction.

But drugs of abuse stimulate this same reward pathway. And when they're used to excess, they may actually take over the normal functioning of the pathway. Core structures of this reward pathway are located in what's known as the limbic system.

So this involves the prefrontal cortex, the very front of that frontal lobe, the nucleus accumbens, and the ventral tegmental area, the VTA. The prefrontal cortex is considered to be the executive centre of the brain. And it's involved in goal-directed behaviours, impulsivity, emotional learning, and sort of consolidation of memories. And the prefrontal cortex is further made up of the medial prefrontal cortex, the orbitofrontal cortex, and the anterior cingulate cortex.
Clinical evidence suggests that the orbitofrontal cortex is involved in some of these critical human functions, such as social awareness and control of mood, drive, responsibility, so traits that are crucial in what we might consider personality of a person. And recent evidence shows this area is also a component of brain systems that are critically engaged in memory, and in reward, and decision-making mechanisms. And several studies have shown that there’s an increase in activity in this orbitofrontal cortex when drug addicts are exposed to drug associated stimuli.

The nucleus accumbens projects to that orbitofrontal cortex via the thalamus. And in turn, the orbitofrontal cortex provides lots of connections back again to the nucleus accumbens. The orbitofrontal cortex also receives direct projections from dopamine cells in that ventral tegmental area. And it also receives input from other areas within the limbic system, like the amygdala and the hippocampus.

Animal models have also enabled us to better understand this reward pathway. So there’s something called the medial forebrain bundle, which connects the septum, the amygdala, and the nucleus accumbens with the hypothalamus and that ventral tegmental area.

And experiments have shown that if that medial forebrain bundle is cut, animals will decrease or even completely stop self-administration of drugs. And again, that medial forebrain bundle contains lots of dopaminergic neurons. So the central reward pathway of the brain sends information to and receives input from many other the brain areas, including the reticular activating system, those limbic regions, the basal ganglia, and the cerebellum.

The reticular activating system is located in the brain stem, and it controls attention and arousal to various sensory inputs from our environment. Limbic regions like the amygdala, the septum, and the thalamus also provide input into the reward pathway concerning motivational and emotional factors. And the reward pathway then interacts with the basal ganglia and the cerebellum to modify motor activity.

The hypothalamus is the seat of the autonomic nervous system. And it serves as a major circuit between these nervous and endocrine systems. The hypothalamus monitors blood nutrient levels and other endogenous compounds in order to maintain homeostasis.

The pituitary also signals secretion of hormones that interact with the reward system and can promote adaptive to behaviours, such as feeding, drinking, and reproduction. So the hypothalamus can be considered the connection centre, integrating the reward pathway with the rest of the body and with environmental stimuli. So to conclude, the reward pathway within the brain involves a large number of structures that all interact with each other and with the environment to determine the response and develop the response to drugs of abuse.

So this is a healthy human brain, fixed in a fixative solution. This is from a gentleman who was in his 70s when he died. So you can see that two hemispheres of the brain. You can see those wrinkles that give it the surface area.

This would be that the frontal areas, the frontal loves, moving into the parietal, the occipital, the temporal underneath, and then the cerebellum and the brain stem underneath the brain there. So this is another healthy brain, again from a gentlemen who was in his ‘80s when he died.
This is just one half. The other half has been frozen, so people needing frozen tissue can request that for their research. You can see the frontal lobe, parietal lobe, occipital lobe at the back. You can see the temporal lobe there and the cerebellum.

And then if we look on the inside—so this brain has been sliced in half—you can see the brain stem here. You can see the cerebellum. And you can see that the corpus callosum that joins the two halves of the brain together. So the midbrain that we talked about, the ventral tegmental area would be in this area. And then our limbic system passes round and into the prefrontal cortex and the orbitofrontal cortex right at the top of the brain.