Unit 5: How do our choices change our brains?

In the previous units, we learned about the neuron, synaptic transmission, and neuronal circuits. In this key culminating unit, we’ll bring all of that knowledge together with a discussion of drug addiction, to understand how our choices affect our brains, as well as how our brains affect our choices.

Remember our graphic from the beginning of this workbook? This unit focuses on how our choices change our brains – so we’re pulling all the information from the previous units together.
What circuits do drugs affect in our brains?

To start our discussion of drug addiction, in this lesson you'll be introduced to the circuit that controls how we experience pleasure — the neural reward circuit.

What is drug addiction?

Drug addiction poses a serious problem to our society. Consider the disastrous effects caused by the abuse of one of our oldest drugs, alcohol: automobile accidents, fetal alcohol syndrome, increase rate of liver disease, increased rate of heart disease, and increased rate of stroke. Or take smoking which causes addiction to nicotine. It greatly increases the chances of dying of lung cancer, heart attack, and stroke.

The term addiction is derived from the Latin word addicere, “to sentence”. Someone who is addicted to a drug is, in a way, sentenced to a term of involuntary servitude, because they are shackled to their drug dependency, which defines how they live their lives.

Addiction is defined as a chronic, relapsing brain disease that is characterized by compulsive drug seeking and use, despite harmful consequences. It is considered a brain disease because drug use changes brain structure and function. These changes can be long lasting, and can lead to the harmful behaviors seen in people who abuse drugs.

How do drugs of abuse work in the brain?

Drugs of abuse interfere with neurotransmission. They do this by altering signaling in the pathway that controls our feelings of reward and pleasure. This pathway is called the dopamine reward pathway. The dopamine reward pathway originates in a subcortical area of the brain near the midline called the ventral tegmental area (VTA). Dopamine neurons whose cell bodies are in the VTA end up in the nucleus accumbens (NAc) and the prefrontal cortex (PFC).
The connections between the VTA and the nucleus accumbens are called the **reward pathway** because the pathway is activated during pleasurable experiences such as eating, sex or receiving praise. Researchers have learned that this pathway is well conserved among animals, making the same connections in our brains as it does in a rodent’s brain (Figure 1).

Since these structures are buried deep within the middle of the brain, you might want to take a look at a 3D model to get a better understanding of where these structures actually are. (We really like the free smart phone app called ‘3-D Brain’.)

**Methods to study drug effects in the brain**

The reward pathway was discovered using the technique of **intracranial self-stimulation** (Figure 2). In these experiments, scientists implanted an electrode in different areas of rats’ brains, and then trained the rats to press a lever to activate the electrode. When the electrode was implanted in the VTA, the rats spent their time compulsively pressing the lever, even at the expense of eating and drinking. The rats didn’t behave like this if the electrode was implanted in areas other than the VTA. Knowing that rats only compulsively repeat behaviors that are pleasurable, the scientists concluded that stimulation of the VTA must activate a pathway that stimulates feelings of pleasure or reward.

You can watch a video about intracranial self-stimulation online — see this unit on the student website or click below:

- Video: Brain Mechanisms of Pleasure and Addiction
A modification of intracranial self-stimulation has been used very effectively in identifying drugs that have the potential to be abused by humans. Based again on the idea that animals only compulsively repeat pleasurable behaviors, if an animal compulsively presses a lever in order to receive an injection of a drug into either their blood or their brain, we can conclude that the drug must have reinforcing properties (meaning that the drug activates the reward pathway and encourages animals to keep repeating the behavior). Using animals and this drug self-administration method, scientists have been able to very accurately predict whether or not a drug is likely to be addictive in humans. For example, rodents will readily self-administer morphine, cocaine and amphetamines, drugs that we know are readily abused by humans. In contrast, drugs like aspirin, antidepressants, and drugs that are used to treat psychoses like schizophrenia, are neither self-administered by animals nor abused by humans.

We can also use this self-stimulation method to ask the animal which of several drugs it prefers by placing two levers in the chamber and training the animal to press lever A for one drug, and lever B for the alternative. Given free access to the levers, the animal’s choice will indicate which drug the animal prefers, because that drug will have greater reinforcing properties.

Additionally, we can ask how much the animal really “likes” a particular drug by varying how hard the animal needs to work to get the drug. For example, we can make the animal press the lever ten times for one injection or sixty-five times for one injection. We can tell how reinforcing the drug is by how many times the animal will press the lever for a single injection. The point at which the effort required exceeds the reinforcing value is called the breaking point – the higher the breaking point, the greater the reinforcement of the drug, and presumably the greater the abuse potential in humans. Drugs like cocaine sustain incredibly high rates of responding: animals will lever-press for drug reinforcement until exhaustion.

Would you expect a rat to self-administer an antibiotic? Why or why not?

**Addicted to _____**

You’ve probably suspected that addiction is not limited to drugs. Many brain parts are interlocking and overlapping, so the reward pathway can get turned on by – well, just about anything.

In addition to the usual physical suspects, you can get hooked on a feeling as well, and that includes (but is not limited to) compulsive behavior such as eating, gambling, shopping, risk taking, and sex. That’s because these feelings, thoughts and sensations hijack our reward pathways. (See Box 5.1 for a description on how food effects our reward pathway.)

Certainly many events and experiences register pleasure, but some things are much more potent than others. All drugs of abuse, for example, prompt a tsunami of dopamine signaling in the reward pathway – a reaction much more powerful than any natural reward. Eventually these reactions overwhelm, capture, and change the reward pathway, leaving us craving more and more.
Various feeding and satiety messages from the body do not single-handedly determine what we eat. Almost everyone has encountered a mouth-watering dessert and devoured it, even on a full stomach. We have an innate taste for sweet and acquire a taste for fat. We often eat because food confronts us. It smells good, tastes good, and looks good. We might eat because it is the right time of day, we are celebrating, or we are trying to overcome sadness. After a meal, memories of pleasant tastes and feelings reinforce appetite, our desire to eat.

Our desire to eat is controlled by the dopamine reward pathway. Scientists have learned that the reward pathway is activated by all pleasurable stimuli, including food. Our reward pathways are particularly sensitive to high-calorie food, containing sugar and fat. This makes sense evolutionarily because as hunters, we did not always succeed in finding something to eat. So high-calorie foods, which contained a lot of energy, offered a survival advantage. In that environment, it was in our best interest to consume as many high-calorie foods as we could find. So our bodies adapted a mechanism to find high-calorie foods rewarding, which motivated us to consume them. But today, when we no longer need to hunt to find our food, our reward pathways are still guiding our food selection to high-calorie foods that are full of sugar and fat.

The involvement of the reward pathway in food selection and consumption is an area of much scientific research. Research indicates that even in the absence of hunger, the sight, smell and even the thought of high-calorie foods can activate the reward pathway and motivate us to consume these foods. Consuming foods to please appetite but not hunger, is one reason why we intake more food than is needed to maintain an energy balance.
Recently, different celebrities have blamed transgressions on ‘addictions’ (i.e. Tiger Woods addicted to sex) – to what extent do you believe that people get addicted to different behaviors? To what extent do you think people are using ‘addiction’ as an excuse?

Since anything that is pleasurable activates the reward pathway, it is technically possible to become addicted to anything that is pleasurable – for example running. Describe how an addiction to running would occur.