

## **Guide to “Neuroscience Behind Drugs of Abuse” presentation High school version**

### **Slide 1: Introduce yourself**

Explain that you will be presenting information on how heroin, marijuana, cocaine, amphetamine and ecstasy alter the brain, and how these alterations cause mood and behavioral changes and eventually lead to addiction. (There are other abused drugs like ethanol and inhalants, with other mechanisms of action, but we will discuss the more popular drugs of abuse today.)

### **Slide 2: Brain regions and neuronal pathways**

Certain parts of the brain govern specific functions. Point to the sensory (blue), motor (orange) and visual cortex (yellow) areas to highlight their specific functions. Point to the cerebellum (pink) for coordination and to the hippocampus (green) for memory. Indicate that nerve cells or neurons connect one area to another via pathways to send and integrate information. The distances that neurons extend can be short or long. For example, point to the reward pathway (red). Explain that this pathway is activated when a person receives positive reinforcement for certain behaviors ("reward"). Indicate that you will explain how this happens when a person takes an addictive drug. As another example, point to the thalamus (magenta). This structure receives information about pain coming from the body (magenta line within the spinal cord), and passes the information up to the cortex. The thalamus is also involved in drug dependence. Tell the audience that you can look at the neuronal connections in more detail.

### **Slide 3: Neuronal Structure:**

Remind the audience that pathways are made up of neurons like these (viewed through a high-powered microscope). Explain the normal direction of impulse flow. Point to the cell on the top and indicate that electrical impulses (the action potential) flow in the direction toward the terminal. Remind the students what happens when impulses reach the terminal; neurotransmitters are released, they bind to their receptors on a second cell, and new impulses are generated in the second cell (on the bottom). Explain that this is how information travels from neuron to neuron.

### **Slide 4: The synapse and synaptic neurotransmission**

Describe the synapse and the process of chemical neurotransmission. As an electrical impulse arrives at the terminal, it triggers vesicles containing a neurotransmitter, such as dopamine (blue teacups), to move toward the terminal membrane. The vesicles fuse with the terminal membrane to release their contents (in this case, dopamine). Once inside the synaptic cleft (the space between the 2 neurons) the dopamine can bind to specific proteins called dopamine receptors (in pink) on the membrane of a neighboring neuron. Activation of these receptors influences the response of the second cell.

### **Slide 5: The reward pathway**

Tell your audience that this is a view of the brain cut down the middle. An important part of the reward pathway is shown and the major structures are highlighted: the ventral tegmental area (VTA), the nucleus accumbens and the prefrontal cortex. The VTA is connected to both the nucleus accumbens and the prefrontal cortex via this pathway and it sends information to these structures via its neurons. The neurons of the VTA contain the neurotransmitter dopamine which is released in the nucleus accumbens and in the prefrontal cortex (point to each of these structures). Reiterate that this pathway is activated by a rewarding stimulus. [Note: the pathway shown here is not the only pathway activated by rewards - other structures are involved too - but only this part of the pathway is shown for simplicity.]

### **Slide 6: Rats, mice self-administer heroin (and other abused drugs)**

Just as a rodent will stimulate itself with a small electrical jolt that activates the reward pathway, it will also press a bar to receive heroin. In this slide, the rat is self-administering heroin through a small needle placed directly into the nucleus accumbens. The rat keeps pressing the bar to get more heroin because the drug makes the rat feel good. The heroin is positively reinforcing and serves as a reward. If the injection needle is placed in an area near the nucleus accumbens, the rat won't self-administer the heroin. Scientists have found that dopamine release is increased within the reward pathway of rats self-administering heroin. Because more dopamine is present in the synaptic space, it binds to more dopamine receptors and activates the reward pathway.

### **Slide 7: Addiction**

Now that you have defined the concept of reward, you can define addiction. Addiction is a state in which an organism engages in a compulsive behavior, even when faced with negative consequences. This behavior is reinforcing, or rewarding, as you have just discussed. A major feature of addiction is the loss of control in limiting intake of the addictive substance. Emphasize that 5% of people get addicted the very first time they try the drug!

The most recent research indicates that the reward pathway may be even more important in the craving associated with addiction, compared to the reward itself. Scientists have learned a great deal about the biochemical, cellular and molecular bases of addiction; it is clear that addiction is a disease of the brain. State that you will provide examples of the interaction between drugs that are addictive, their cellular targets in the brain, and the reward pathway.

### **Slide 8: The likelihood of addiction may be related to dopamine D2 receptor levels**

Scientists have recently discovered that levels of a particular type of dopamine receptor may be low in areas of the brain associated with reward. The 6 brain scans indicate the extent that dopamine D2 receptors in reward areas of the brain are available to bind a radioactive mimic of dopamine. For each of the 3 abused drugs shown, addicted individuals showed fewer D2 receptors than "controls" (non-drug abusers).

The cartoons on the right are meant to show that because the drug addict has fewer dopamine D2 receptors, the reward circuits are optimally activated by the abused drug. The non-drug abuser, on the other hand, has "overloaded" circuits in the presence of the drug. This is actually believed to cause an aversive (unpleasant) response so that these individuals are less likely to abuse the drug. (Dopamine affects not only reward but motivation, emotion, attention and motor function.) At this point, mention that abused drugs cause 5 to 10 times more dopamine release into reward circuits than do "natural reinforcers" (food, sex, socialization). For the natural reinforcers, the number of dopamine receptors is optimal for pleasure/reward in non-drug abusers, but the receptor number is inadequate for drug addicts. Thus, most drug-addicted individuals get little pleasure from natural reinforcers, and a great deal of pleasure from drugs of abuse.

This is the most conceptually-difficult slide in the presentation, and you may be asked how too much dopamine can be aversive, or otherwise be asked to defend the slide. If necessary, you might want to mention a study that used gene therapy to introduce more dopamine D2 receptors in the "reward" brain region of mice. This study showed that artificially increasing the D2 receptor level in this way caused decreased intake of abused drugs.

Finally, emphasize that D2 receptor levels are significantly different among people never exposed to drugs of abuse. In other words, low D2 receptor levels in addicts were probably present even before the drug abuser experienced such drugs. One study involving people who had never used drugs of abuse separated the subjects into "high" and "low" D2 receptor level groups. When all were given a small amount of a drug that causes increased dopamine levels, only the "low" group enjoyed the experience. We would predict

that the group with lower D2 levels is more likely to become addicted to drugs of abuse from experimenting with drugs.

### **Slide 9: Brain regions controlling compulsive behavior may function differently in cocaine abusers**

Another recent discovery is that the frontal lobe of the brain is less active in cocaine abusers. A portion of this lobe controls impulsive and compulsive behaviors; a low level of brain function here corresponds to compulsive drug intake. This suggests that the brains of cocaine addicts are unable to prevent compulsive drug taking, just as you are unable to prevent flinching when a snake springs toward your leg. In fact, drug addicts often say that they don't get much pleasure out of the drug anymore, but they just can't stop taking the drug - it's a reflex. This suggests that drug addiction is not a matter of "willpower", but rather an obsessive-compulsive disorder.

### **Slide 10: The memory for drugs**

This slide demonstrates how just the mention of items associated with drug use may cause an addict to "crave" or desire drugs. This PET scan is part of a study that compared recovering addicts, who had stopped using cocaine, with people who had no history of cocaine use. The study hoped to determine what parts of the brain are activated when drugs are craved. The PET scan (positron emission tomography) measures brain activity in real time by tracking an injected radiochemical (e.g., 2-deoxyglucose, dopamine, serotonin).

For this study, brain scans were performed while subjects watched two videos. The first video, a nondrug presentation, showed nature images—mountains, rivers, animals, flowers, trees. The second video showed cocaine and drug paraphernalia, such as pipes, needles, matches, and other items familiar to addicts.

This is how the memory for drugs works: The yellow area on the upper part of the second image is the amygdala (a-mig'-duh-luh), a part of the brain's limbic system, which is responsible for evoking emotions and is also critical for memory. For an addict, when a drug craving occurs, the amygdala becomes active and a craving for cocaine is triggered.

So even if it's the middle of the night and raining, this craving demands the drug immediately. Rational thoughts are dismissed by the uncontrollable desire for drugs. At this point, a basic change has occurred in the brain. The person is no longer in control. This changed brain makes it almost impossible for drug addicts to stay drug-free without professional help. Because addiction is a brain disease.

### **Slide 11: The action of heroin (morphine)**

Heroin is an addictive drug, although not all users become addicted; other factors are important in producing addiction, such as the environment and the personality (genetics) of the user. Heroin produces euphoria or pleasurable feelings and can be a positive reinforcer by interacting with the reward pathway in the brain. Heroin enters the brain quickly, and is then converted to morphine before reaching the brain receptor. Emphasize that oxycontin and methadone work exactly the same way.

### **Slide 12: Localization of opiate binding sites**

Point to the areas where opiates concentrate. The VTA, nucleus accumbens, caudate nucleus and thalamus are highlighted. The opiates bind to opiate receptors that are concentrated in areas within the reward system. Indicate that the action of opiates in the thalamus contributes to their ability to produce both pain relief (analgesia) and dependence.

### **Slide 13: Opiate effects**

By comparison with the previous slide, point out that heroin affects judgment, sensation, pain, reward and dependence, but NOT vision, coordination, etc..

### **Slide 14: Morphine binding to opiate receptors in the nucleus accumbens - activation of dopamine release**

First, indicate that Cell #1 (upper left), Cell #2 (bottom) and Cell #3 (upper right) form a synapse.

Cell #3 normally inhibits release of dopamine from Cell #1. Morphine activation of opiate receptors on Cell #3 decreases Cell #3's ability to inhibit Cell #1 (inhibition of inhibition), meaning that more dopamine is released from Cell #1. Thus, more dopamine is received by Cell #2, increasing reward/reinforcement/addiction.

Explain that during normal brain function, opiate receptors are activated by endorphins which serve to release dopamine in the same way in response to pleasure or pain.

### **Slide 15: Definition of tolerance**

When drugs such as heroin are used repeatedly over time, tolerance may develop. Tolerance occurs when the person no longer responds to the drug in the way that person initially responded. Stated another way, it takes a higher dose of the drug to achieve the same level of response obtained initially. In the case of heroin or morphine, tolerance develops rapidly to the painkilling effects of the drug. (The development of tolerance is not addiction, although many drugs that produce tolerance also have addictive potential.) Tolerance to drugs can be produced by several different mechanisms, but in the case of morphine or heroin, tolerance develops at the level of the cellular targets. For example, when morphine binds to opiate receptors, it triggers the inhibition of an enzyme (adenylate cyclase) that orchestrates several chemicals in the cell to maintain the firing of impulses. After repeated activation of the opiate receptor by morphine, the receptor adapts so that the morphine can no longer cause changes in cell firing. Thus, the effect of a given dose of morphine or heroin is diminished.

You might mention that fatal overdoses may occur when an addict abruptly stops using heroin for a week or more (in jail, rehab, etc.) and "resensitizes", then goes back on the street and takes the very high amount of the drug that (s)he's used to. (Another reason to treat chronic drug abusers over months and years.)

You might also mention that tolerance at a different (GABA, and possibly NMDA) brain receptor explains why one must consume more and more alcoholic drinks over weeks to obtain the same "high". This is dangerous because the higher ethanol levels irreversibly damage the brain, liver and other organs.

### **Slide 16: Definition of dependence**

With repeated use of heroin, dependence also occurs. Dependence develops when the neurons adapt to the repeated drug exposure and only function normally in the presence of the drug. When the drug is withdrawn, several physiological reactions occur. These can be mild (e.g., caffeine and headaches) or even life threatening (e.g., for alcohol). This is known as the withdrawal syndrome. In the case of heroin, withdrawal can be very serious and the abuser will use the drug again to avoid the withdrawal syndrome.

Mention that heroin addicts typically keep using the drug not to get high, but to avoid getting sick.

### **Slide 17: Addiction vs. dependence**

Different parts of the brain are responsible for the addiction and dependence to heroin and other opiates. Review the areas in the brain underlying the addiction to morphine (reward pathway) and those underlying the dependence to morphine (thalamus and brainstem). Thus, it is possible to be dependent on morphine, without being addicted to morphine. (Although, if one is addicted, they are most likely dependent as well.) This is especially true for people being treated chronically with morphine for pain, for example associated with terminal cancer. They may be dependent--if the drug is stopped, they suffer a withdrawal syndrome. But, they are not compulsive users of the morphine, and they are not addicted. Finally, people treated with morphine in the hospital for pain control after surgery are unlikely to become addicted; although they may feel some of the euphoria, the analgesic and sedating effects predominate. There is no compulsive use and the prescribed use is short-lived.

### **Slide 18: Control centers in the brain are affected by marijuana**

Marijuana disables or disrupts important brain functions. When someone smokes marijuana, the chemical THC (delta-9-tetrahydrocannabinol), the main psychoactive ingredient in marijuana, travels quickly to the brain. We can see the areas of the brain (in pink) where THC concentrates. You can see that THC builds up in areas that control the body's movements, balance, coordination, memory and judgment abilities, and sensations. (Flip back and forth between this slide and the one following it.) THC disrupts your brain's ability to control these activities as well as you could normally.

Note that THC does not bind as extensively to the thalamus or brainstem, the areas associated with physical dependence. This explains why people usually don't become DEPENDENT on pot. People may still become ADDICTED to marijuana, in that they cannot stop using despite adverse consequences, and marijuana use usually encourages experimentation with drugs that do cause physical dependence. THC saturates the hippocampus (memory center), and studies suggest that long-term marijuana use causes permanent damage to this brain structure, leading to deficits in memory recall and in the ability to form memories.

The cannabinoid receptors that recognize THC are similar in nature to opiate receptors in that they control levels of cAMP and other "second messenger" neuromodulators.

### **Slide 19: Opiate binding sites**

Compare to preceding marijuana/THC slide to explain why people are physically dependent on heroin but not marijuana.

### **Slide 20: Brain regions**

Compare to preceding two slides to explain how marijuana and opiates differ in their effects.

### **Slide 21: Alcohol**

- Girls metabolize ethanol slower, so levels of alcohol stay high and cause more cell death. Many studies show that women sustain more brain damage from alcohol in later life.
- Liver cirrhosis, cardiac myopathies (tissue damage from ~10 years drinking) and arrhythmias (sudden death in young alcoholics), gastritis and ulcers, pancreatitis.
- Some of the "shrinkage" studies focused on 13 – 17 year olds.

### **Slide 22: Brain alterations from chronic alcohol use**

The enlarged ventricles of the alcoholic have pushed the corpus callosum upward; the callosum is also thinner. The degeneration of the callosum leads to agitation and dementia, and in some cases seizures, coma and death.

### **Slide 23: Inhalants**

- We don't want to give the students ideas about how to find sources of euphoric inhalants, so don't talk about specific products (e.g., vanilla extract, PAM cooking spray canisters). Just mention that chemicals such as toluene, acetone and nitrous oxide found in these products can cause irreversible brain damage or death.
- SSDS is cardiac arrest, often fatal even in teenagers, due to the inhalant causing an arrhythmia.
- The bone damage refers to chemicals like benzene damaging marrow cells, which may cause leukemia.
- The next slide covers inhalant brain damage.

### **Slide 24: Brain damage from inhalants**

- A. Inhalants can dissolve the myelin sheath around neurons, killing these cells.
- B. Death of cortex cells causes permanent personality changes, learning disabilities, and memory impairment.
- C. Cerebellar damage – Loss of coordination, tremors, uncontrollable shaking, slurred speech
- D. Damage from toluene results in vision losses

### **Slide 25: Dextromethorphan and other OTC drugs**

High levels of dextromethorphan from massive amounts of Coricidin and other cold medicines cause trance-like states, paranoia and rage, much like that seen with angel dust (PCP). These high levels also cause hyperthermia, seizures, coma and death. There have been many teenage deaths from this drug, as well as several murders committed by young people while under its influence.

### **Slide 26: The action of cocaine**

Cocaine is also an addictive drug, and like heroin, not all users become addicted. However, with the advent of crack (free base) cocaine, the rate of addiction to cocaine has increased considerably.

### **Slide 27: Snorting vs smoking cocaine: different addictive liabilities**

Historically, cocaine abuse involved snorting the powdered form (the hydrochloride salt). When cocaine is processed to form the free base, it can be smoked. Heating the hydrochloride salt form of cocaine will destroy it; the free base can be volatilized at high temperature without any destruction of the compound. Smoking gets the drug to the brain more quickly than does snorting. Show the audience why this happens. Snorting requires that the cocaine travels from the blood vessels in the nose to the heart (blue arrow), where blood gets pumped to the lungs (blue arrow) to be oxygenated. The oxygenated blood (red arrows) carrying the cocaine then travels back to the heart where it is pumped out to the organs of the body, including the brain. However, smoking bypasses much of this--the cocaine goes from the lungs directly to the heart and up to the brain. The faster a drug with addictive liability reaches the brain, the more likely it will be abused. Thus, the time between taking the drug and the positive reinforcing or rewarding effects that are produced can determine the likelihood of abuse.

Still, the bottom line is that snorted cocaine can be just as addictive as crack cocaine - some addicts have actually said that they didn't know that the snorted form could get them addicted!

### **Slide 28: Long-term effects of drug abuse**

This PET scan shows us that once addicted to a drug like cocaine, the brain is affected for a long, long time. In other words, once addicted, the brain is literally changed. Let's see how.

In this slide, the level of brain function is indicated in yellow. The top row shows a normal-functioning brain without drugs. You can see a lot of brain activity. In other words, there is a lot of yellow color.

The middle row shows a cocaine addict's brain after 10 days without any cocaine use at all. What is happening here? [Pause for response.] Less yellow means less normal activity occurring in the brain—even after the cocaine abuser has abstained from the drug for 10 days.

The third row shows the same addict's brain after 100 days (almost a third of a year!) without any cocaine. We can see a little more yellow, so there is some improvement—more brain activity—at this point. But the addict's brain is still not back to a normal level of functioning. Scientists are concerned that there may be areas in the brain that never fully recover from drug abuse and addiction.

### **Slide 29: Dopamine binding to receptors and uptake pumps in the nucleus accumbens - The action of cocaine**

Explain that cocaine binds to sites in areas of the brain that are rich in dopamine synapses such as the VTA and the nucleus accumbens. Review dopamine transmission in the close-up of a synapse in the nucleus accumbens. Point to dopamine (inside the terminal) that is released into the synaptic cleft. The dopamine binds to dopamine receptors and then is taken up by uptake pumps (transporter proteins) back into the terminal. Now show what happens when cocaine is present (yellow). Cocaine binds to the uptake pumps and prevents them from transporting dopamine back into the neuron terminal. So more dopamine builds up in the synaptic space and it is free to activate more dopamine receptors. [This is the same effect that you showed in an earlier slide with morphine, where morphine increased dopamine release from the terminal to produce more dopamine in the synaptic cleft.]

### **Slide 30: Define “ecstasy”**

Ecstasy is a derivative of amphetamine (shown in purple on the slide). Its chemical name is 3,4-methylenedioxy-N-methylamphetamine (MDMA) and it has a similar structure to methamphetamine. Ecstasy has a variety of street names. Explain to students that ecstasy is unlike other drugs of abuse, which are often derived from plants (e.g., cocaine, morphine, nicotine). In contrast, ecstasy is synthesized in secret, illegal laboratories (as is heroin) --in fact, there are several “designer drugs” that are made by altering the structure of the amphetamine molecule. Purity can vary substantially from lab to lab, and other compounds are easily combined into the same tablet (contaminants often include caffeine, ephedrine, ketamine (a mild hallucinogen) and methamphetamine).

This modification of amphetamine decreases its ability to activate the receptors responsible for the "speed" effect (rapid HR, etc.) but retains mood-altering properties.

### **Slide 31: Short-term (acute) effects of ecstasy:**

Explain that when a person uses ecstasy, the increase in serotonin (and dopamine) in different brain regions (i.e. the areas where serotonin neurons traveling from the raphe nucleus terminate) causes psychological effects. These include elevated mood and feelings of empathy. Ecstasy is also reinforcing; this means that

its pleasurable properties increase the likelihood that the person will take it again. Tell the students that drugs that are reinforcing are usually addictive.

Students might ask you if ecstasy is addictive. Scientists and health professionals don't have a definitive answer yet, because ecstasy use has not reached the level of cocaine abuse (although, if ecstasy use continues to rise at the current rate, it will be only a matter of time until we see that ecstasy, like other amphetamines, is addictive.) For now, there are several pieces of evidence that suggest that ecstasy has the potential to be addictive. For example, in a research setting, monkeys will administer ecstasy to themselves (they actually press a lever to obtain an injection), just as they do for other addictive drugs. Monkeys will not self-administer drugs that are not addictive. In addition, there is emerging research to show that ecstasy has actions in the 'reward pathway', which can explain its reinforcing effects.

Many of the psychological effects of ecstasy are due to its actions within the limbic system (the amygdala, in red, and hippocampus, in blue, especially). The ability of ecstasy to produce mild stimulation is due to its actions in another part of the limbic system -- the basal ganglia (in purple). It is here where ecstasy's effects on the dopamine system may be important. The heightened perceptions involve the actions of ecstasy in the neocortex (in yellow). Ecstasy can also reduce the appetite, because it acts in the hypothalamus (in green), which controls feeding behavior.

### **Slide 32: Short-term adverse effects of ecstasy**

People who take ecstasy desire its pleasurable or reinforcing effects (just described above). However, few drugs are able to produce desirable effects without also producing side effects. Ecstasy is no exception, and there are several side effects or adverse effects that can occur, especially if the dose increases. Some people who take only one (uncontaminated) ecstasy pill may have negative psychological effects such as clouded thinking, agitation and disturbed behavior. Point to areas of the brain where ecstasy may produce these adverse effects (the neocortex, in yellow and limbic structures, in red and blue). Other adverse effects can occur as well. These include sweating, dry mouth (thirsty), increased heart rate, fatigue, muscle spasms (especially jaw-clenching) and hyperthermia. In the latter case, ecstasy can disrupt the ability of the brain to regulate body temperature. This usually results in hyperthermia, especially when the user is in a hot environment and/or engaging in intense physical activity such as dancing at rave parties. You can provide some examples to show where ecstasy produces these side effects. For example, the development of thirst and the hyperthermia are due to actions of ecstasy in the hypothalamus (green), which controls drinking behavior and body temperature. You might point out that the effect of ecstasy on the hypothalamus causes multiple effects in the body, and in some cases they are very dangerous (see the next slide). The muscle spasms and jaw-clenching are due to ecstasy's action at the motor neurons in the spinal cord (in yellow) (remind the students that a major serotonin pathway descends down the spinal cord). The motor neurons send signals to the muscles to contract.

### **Slide 33: Life-threatening effects after multiple doses (“stacking”)**

Some people take multiple doses of ecstasy in one night (“stacking”) This might be due to the reinforcing effect of the drug (if something feels good, one wants to do it again). Unfortunately, the increased dose also increases the adverse effects, and some of these can become life-threatening. For example, repeated doses or a high dose of ecstasy can cause injury due to hyperthermia, hypertension (high blood pressure), cardiac arrhythmias (irregular heart beat), muscle breakdown and renal failure due to salt and fluid depletion. Indicate that these dangerous effects can be produced by ecstasy acting in the brain. Again, the hypothalamus is very important, because it regulates heart rate and blood pressure, fluid retention and kidney function, and of course, body temperature. If the body temperature gets too high, it can cause brain damage or even kill a person.

A paramethoxyamphetamine (PMA) pill may look identical to one containing ecstasy alone. Because PMA is 3 times more potent than ecstasy, one PMA pill could kill you (cite the case of the 16 year old PGH girl at a rave - core temp. of 109°F at death).

At the risk of sermonizing, I would point out here the illogic of taking a substance of unknown history. Ask the students, "Would you use a bottle of Tylenol from the store if the seal had been broken and the bottle was half empty or the pills didn't look right?" And: "Even if your best friend gave you the drug, do you think (s)he knows anything about its preparation?"

#### **Slide 34: Ecstasy and serotonin transporters**

When ecstasy binds to the serotonin transporters, more serotonin ends up in the synaptic space. This occurs for two reasons. First, ecstasy can prevent the transporters from carrying serotonin back into the terminal. Second, ecstasy can cause the transporters to work in reverse mode-- they actually bring serotonin from the terminal into the synaptic space. (Ecstasy is transported into the terminal and flushes serotonin out into the synapse.) So, more serotonin is present in the synaptic space and more serotonin receptors become activated. This is the major short-term effect of ecstasy that alters brain chemistry. The primary difference between cocaine and ecstasy is that cocaine cannot be transported into the terminal. This is why cocaine's effects last less than 30 minutes and ecstasy's effects last for several hours.

While the serotonin system is the primary target for ecstasy, ecstasy has similar effects on the dopamine (another neurotransmitter) system as well. Ecstasy can inhibit dopamine transporters and cause an increase in dopamine levels in the synaptic space (not shown here). Remind the students that dopamine is the neurotransmitter primarily responsible for addiction. To help students understand how the alteration in brain chemistry results in psychological changes, go to the next slide.

#### **Slide 35: Short-term effects after ecstasy is gone from the body**

Ecstasy is an unusual drug because it has effects on the brain that develop and persist for a short time after the drug is eliminated from the body. These often include the development of depression-like feelings, anxiety, restlessness, irritability and sleep disturbances. These "aftereffects" occur because of a chemical change that takes place at the serotonin synapse. To illustrate how this occurs, this slide shows the serotonin synapse during and after taking ecstasy. Three conditions are illustrated: On the left, neurons normally release serotonin in response to electrical impulses (basically the release is in "spurts"). This results in the normal activation of serotonin receptors, which keeps our psychological and physiological function on an even keel. So, for example, we have a normal mood and we are calm. In the middle panel, ecstasy causes a sustained increase in the amount of serotonin in the synaptic space, leading to sustained activation of more serotonin receptors. This can produce an elevated mood (or euphoria), similar to the action of antidepressant drugs. (At this point ask students how the 3rd (rightmost) figure differs from the 1st figure.)

Eventually, the serotonin neurons can't make serotonin fast enough to replace that which was lost, so once ecstasy is gone from the body (on the right), less serotonin is released with each electrical impulse and fewer serotonin receptors are activated, producing depression-like feelings and anxiety. Another important effect that emerges after taking ecstasy is memory disruption. (Ask students if they can figure out which area of the brain is affected here - the answer should include the cerebral cortex and the hippocampus). This is the one adverse effect that may be permanent with repeated or long-term use of ecstasy. Indicate to students that there is considerable evidence for this obtained from animals and from humans.

#### **Slide 36: Long-term effects of ecstasy**

This slide shows sections taken from the neocortex of monkeys that were given ecstasy twice a day for 4 days (control monkeys were given saline) and then never saw the drug again. The section on the left, taken from the brain of a control monkey, shows the presence of a lot of serotonin (immunostaining with an antibody against serotonin). The middle section shows a section from a monkey two weeks after receiving ecstasy. Point out that most of the serotonin is gone. The section on the right shows a section from a

monkey 7 years after receiving ecstasy. Point out that although there has been some recovery of serotonin (about 30% of the control), the brain still has not returned to normal.

### **Slide 37: Prescription drug abuse facts**

The slide is fairly self-explanatory; just emphasize that prescription drug abuse is the new #1 enemy because these drugs are easier to obtain and there's less public knowledge about their toxic effects.

### **Slide 38: Prescription drug misuse: Michael Jackson and Heath Ledger**

Prescription drug misuse is often the result of dealing with chronic pain or insomnia, not from trying to get high. Michael Jackson had severe insomnia, and found a doctor who gave him a sleep aid so potent and dangerous that it is normally used only for anesthesia in the operating room. The drug, Diprivan, was also mixed with Ativan, a common sleeping pill.

Heath Ledger (the Joker in the latest "Batman" movie) had long-term pain and insomnia, and used several prescription painkillers and sleeping pills. His autopsy revealed traces of the opiate painkillers Vicodin and Oxycontin and the sleep aids Valium, Xanax, Restoril and Unisom. Used correctly and at varying times, these drugs could have successfully treated his chronic pain and insomnia. Unfortunately, most people take the drugs too frequently so that they become tolerant and no longer get the painkilling and sleep-inducing effects. Worse, you do not become tolerant to the respiratory depression caused by the two opiates, and this is what killed Mr. Ledger – the opiates shut down his brain's automatic breathing mechanism during sleep. Also, erratic use of the sleep aids listed above are known to cause irritability, paranoia and rage.

The bottom line is that you have to be extremely careful about which medications (and the amounts) you're taking at the same time. Taking a prescription drug in a way not recommended by your doctor could result in stroke, paralysis, heart attack, kidney or liver failure, or death.

### **Slide 39: The End**

Mention that many of the slides shown today can be found at the NIDA website, along with much information on other drugs of abuse.

Please encourage questions and discussion (while keeping the presentation to its timetable). Ask the students to e-mail me if they have further questions at [surratt@duq.edu](mailto:surratt@duq.edu) (write my e-mail address on the board).

We would appreciate your staying around as long as you are in demand to discuss these issues with the students. Thanks!

-CKS