Dopamine Is _____?

Is it love? Gambling? Reward? Addiction?

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THE STATE OF THE UNIVERSE.
JULY 3 2013

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In a brain that people love to describe as "awash with chemicals," one chemical always seems to stand out. Dopamine: the molecule behind all our most sinful behaviors and secret cravings. Dopamine is love. Dopamine is lust. Dopamine is adultery. Dopamine is motivation. Dopamine is attention. Dopamine is feminism. Dopamine is addiction.

My, dopamine's been busy.

Dopamine is the one neurotransmitter that everyone seems to know about. Vaughn Bell once called it the Kim Kardashian of molecules, but I don't think that's fair to dopamine. Suffice it to say, dopamine's big. And every week or so, you'll see a new article come out all about dopamine.

So *is* dopamine your cupcake addiction? Your gambling? Your alcoholism? Your sex life? The reality is dopamine has something to do with all of these. But it *is* none of them. Dopamine is a chemical in your body. That's all. But that doesn't make it simple.

What is dopamine? Dopamine is one of the chemical signals that pass information from one neuron to the next in the tiny spaces between them. When it is released from the first neuron, it floats into the space (the synapse) between the two neurons, and it bumps against receptors for it on the other side that then send a signal down the receiving neuron. That sounds very simple, but when you scale it up from a single pair of neurons to the vast networks in your brain, it quickly becomes complex. The effects of dopamine release depend on where it's coming from, where the receiving neurons are going and what type of neurons they are, what receptors are binding the dopamine (there are five known types), and what role both the releasing and receiving neurons are playing.

And dopamine is busy! It's involved in many different important pathways. But when most people talk about dopamine, particularly when they talk about motivation, addiction, attention, or lust, they are talking about the dopamine pathway known as the mesolimbic pathway, which starts with cells in the ventral tegmental area, buried deep in the middle of the brain, which send their projections out to places like the nucleus accumbens and the cortex. Increases in dopamine release in the nucleus accumbens occur in response to sex, drugs, and rock and roll. And dopamine signaling in this area is changed during the course of drug addiction. All abused drugs, from alcohol to cocaine to heroin, increase dopamine in this area in one way or another, and many people like to describe a spike in dopamine as "motivation" or "pleasure." But that's not quite it. Really, dopamine is signaling feedback for predicted rewards. If you, say, have learned to associate a cue (like a crack pipe) with a hit of crack, you will start getting increases in dopamine in the nucleus accumbens in response to the *sight* of the pipe, as your brain predicts the reward. But if you then don't get your hit, well, then dopamine can decrease, and that's not a good feeling. So you'd think that maybe dopamine predicts reward. But again, it gets more complex. For example, dopamine can increase in the nucleus accumbens in people with post-traumatic stress disorder when they are experiencing heightened vigilance and paranoia. So you might say, in this brain area at least, dopamine isn't addiction or reward or fear. Instead, it's what we call salience. Salience is more than attention: It's a sign of something that needs to be paid attention *to*, something that stands out. This may be part of the mesolimbic role in attention deficit hyperactivity disorder and also a part of its role in addiction.

But dopamine itself? It's not salience. It has far more roles in the brain to play. For example, dopamine plays a big role in starting movement, and the destruction of dopamine neurons in an area of the brain called the substantia nigra is what produces the symptoms of Parkinson's disease. Dopamine also plays an important role as a hormone,

inhibiting prolactin to stop the release of breast milk. Back in the mesolimbic pathway, dopamine can play a role in psychosis, and many antipsychotics for treatment of schizophrenia target dopamine. Dopamine is involved in the frontal cortex in executive functions like attention. In the rest of the body, dopamine is involved in nausea, in kidney function, and in heart function.

With all of these wonderful, interesting things that dopamine does, it gets my goat to see dopamine simplified to things like "attention" or "addiction." After all, it's so easy to say "dopamine is X" and call it a day. It's comforting. You feel like you know the truth at some fundamental biological level, and that's that. And there are always enough studies out there showing the role of dopamine in X to leave you convinced. But simplifying dopamine, or any chemical in the brain, down to a single action or result gives people a false picture of what it is and what it does. If you think that dopamine is motivation, then more must be better, right? Not necessarily! Because if dopamine is also "pleasure" or "high," then too much is far too much of a good thing. If you think of dopamine as *only* being about pleasure or only being about attention, you'll end up with a false idea of some of the problems involving dopamine, like drug addiction or attention deficit hyperactivity disorder, and you'll end up with false ideas of how to fix them.

The other reason I don't like the "dopamine is" craze is because the simplification takes away the wonder of dopamine. If you believe "dopamine is," then you'd think that we've got it all figured out. You begin to wonder why we haven't solved this addiction problem yet. Complexity means that the diseases associated with dopamine (or with any other chemical or part of the brain, for that matter) are often difficult to understand and even more difficult to treat.

By emphasizing dopamine's complexity, it might feel like I'm taking away some of the glamour, the sexiness, of dopamine. But I don't think so. The complexity of how a neurotransmitter behaves is what makes it wonderful. The simplicity of a single molecule and its receptors is what makes dopamine so flexible and what allows the resulting systems to be so complex. And it's not just dopamine. While dopamine has just five receptor type, another neurotransmitter, serotonin, has 14 currently known and even more that are thought to exist. Other neurotransmitters have receptors with different *subtypes*, all expressed in different places, and where each combination can produce a different result. There are many types of neurons, and they make billions and billions of connections. And all of this so you can walk, talk, eat, fall in love, get married, get divorced, get addicted to cocaine, and come out on top of your addiction some day. When you think of the sheer number of connections required simply for you to read and understand this sentence—from eyes to brain, to processing, to understanding, to movement as your fingers scroll down the page—you begin to feel a sense of awe. Our brain does all this, even while it makes us think about pepperoni pizza and what that text your crush sent *really* means. Complexity makes the brain the fascinating and mind-boggling thing that it is.

So dopamine has to do with addiction, whether to cupcakes or cocaine. It has to do with lust and love. It has to do with milk. It has to do with movement, motivation, attention, psychosis. Dopamine plays a role in all of these. But it *is* none of them, and we shouldn't want it to be. Its complexity is what makes it great. It shows us what, with a single molecule, the brain can do.