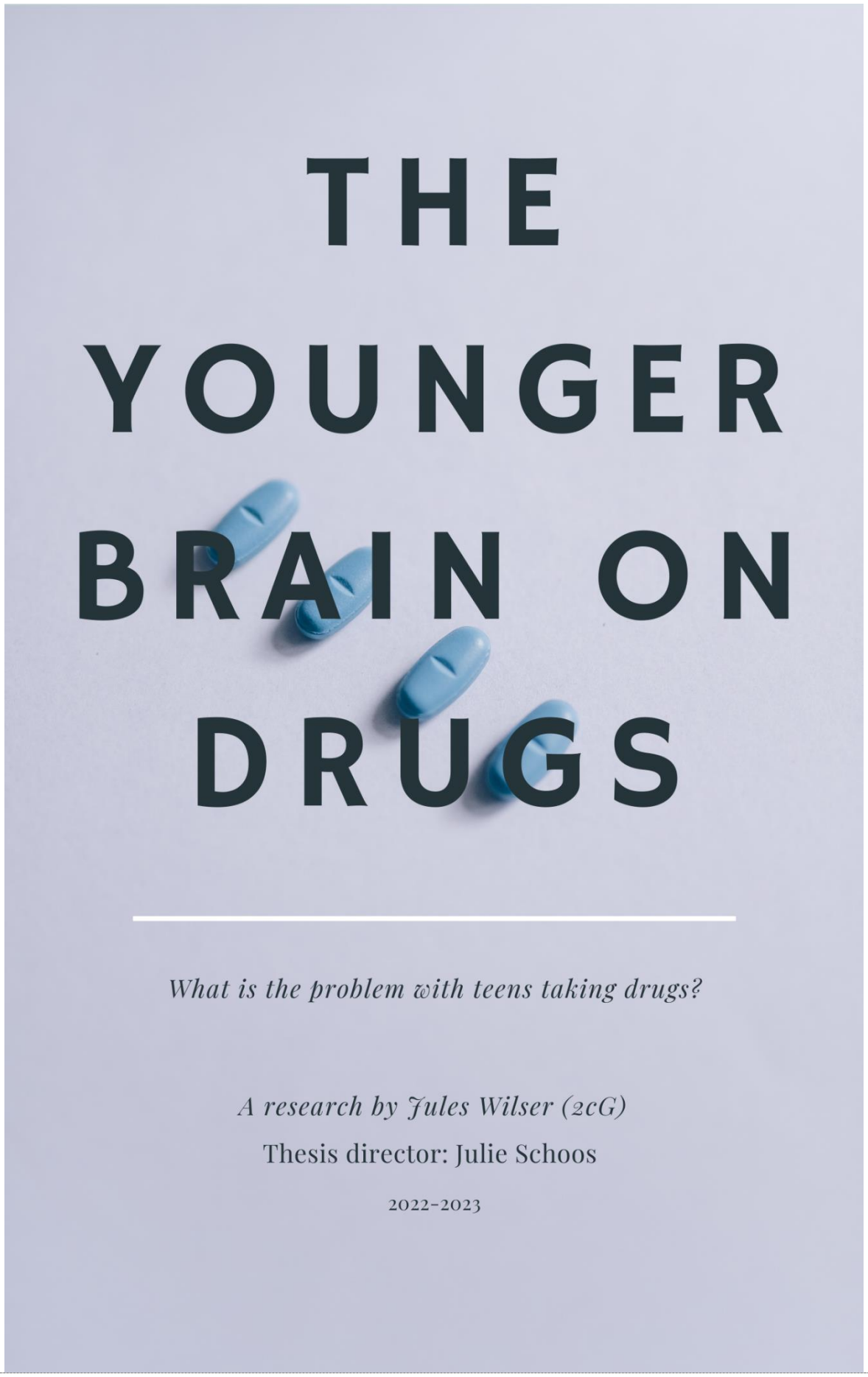

THE YOUNGER BRAIN ON DRUGS

What is the problem with teens taking drugs?

A research by Jules Wilser (2cG)

Thesis director: Julie Schoos

2022-2023

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Introduction

Since my childhood (due to the fact that my mother is a researcher and teacher at the University of Luxembourg) I've always heard about neurosciences and psychology. With time passing by I've grown quite an interest myself in our brain's way to observe, take decisions, and deal with given problems too. Prior to last year I've only read some papers about psychology, watched some documentaries and videos about it, and I wrote my second TraPe about how marketing uses neuroscience and psychology in its favour. Besides that, I've never really thought about exploring this growing interest more or about trying to make a living with it until I had a serious talk with my mother about it. That was the moment that I realised and decided that psychology is what I want to build my life upon. And what better time to start than right now.

When I was about 14 years old, I used to skate a lot. I discovered another part of my environment that I never got to experience before. Like most other people I met a lot of individuals coming from different backgrounds. This may sound very stereotypical, and I do not want to talk down on the skating community, but at my time this was a whole new world for me. In almost every aspect of life. Early teenhood is often the first time that kids start to get more independent and get more free time. At least that was my experience and also the one kids in my surroundings got to experience. Because skating is an activity that is often times practiced outdoors and not supervised by any adults it can be easier to use recreational drugs such as cannabis, alcohol and even harder drugs. Furthermore, because there are no age restrictions, people of all ages get mixed together and the younger public can quite easily get involved into business that - let's say it like this: is less than ideal for the young brain's proper development. This is in my opinion the reason why this environment that can expulse kids out of their innocence a lot too soon.

At my time, this was when people my age, often friends of mine started to try these recreational drugs and consume them without any knowledge about them and without concern for their health. Since I talked about my friends with my parents, they somewhat knew what was going on in my environment. Although this was no safe place for me, instead of depriving me of my freedom or to ground me, they explained in simple words what drugs and alcohol would do to my brain. They gave me a choice. Four years later, I can confirm that they made the right choice because even if I was in a dangerous environment, I can now say with confidence that looking back into the situations I once was in, I think I was able to make the right choices because of my background and because of my parents talks. This is also the true reason I wanted to write this memoire. It is why I think that knowledge is key to making the right choices. I will try to enlighten the readers of this research as much as possible about different recreational drugs and why it is best not to consume them in general and especially not at a young age. I will hopefully arm you with enough neuroscientific facts that the next time you'll want to consume one of these substances you will know the harm it will cost your brain. But first you will need to learn the basics of your brain which is also the very first step beginning with chapter one.

The Brain

A brief look into the brain's functioning

Anatomy

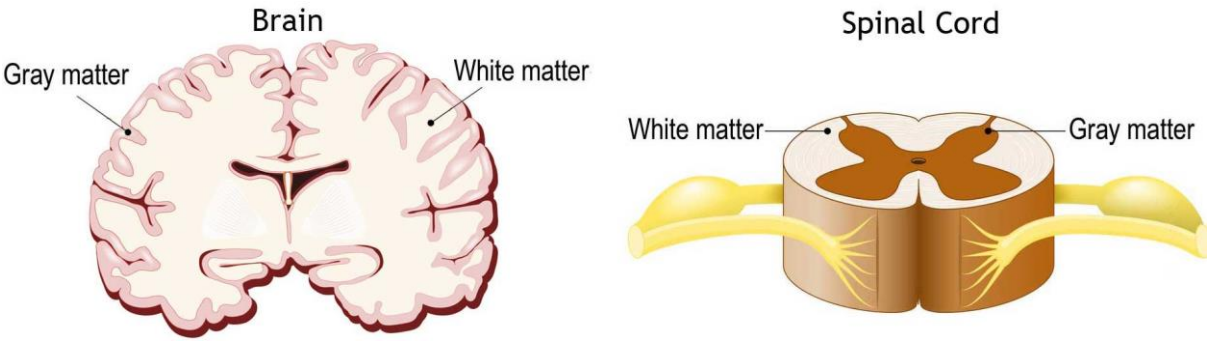
Also referred to as the central nervous system, the brain and the spinal cord that extends from it controls our thought, memory, touch, motor skills, and every process that regulates our body. Being the most important organ in the nerve system, this research is about how the young brain reacts neurologically and mentally to different kinds of substances, I'm going to take the time needed to briefly explain the brains anatomy and how it works. In my opinion, understanding what drugs do to one's brain is essential to spread awareness about the consequences substance abuse cause.

The brain, as a single organ can be subdivided into different regions serving different roles such as processing different information, memorizing things and other tasks.

- *What is our brain made of?*

To get started with it is important to know that the brain consists of so called grey and white matter.

The grey matter consists of the outer layer of the brain (the neuron "bodies", meaning the part of the nerve cells containing the nucleus) while the white matter is the tissue underneath it. The grey matter also extends from the brain into the spinal cord. However, in the spinal cord the order is reversed meaning that the interior consists of grey matter which is surrounded by white matter.



Grey and white matter: https://www.hopkinsmedicine.org/health/conditions-and-diseases/anatomy-of-the-brain

These different tissues primarily consist of cell bodies and nerve fibres and the composition of neuron parts that these two tissues are the reason one appears whiter and the other darker.

These two regions each serve different roles. While grey matter is responsible for the processing and interpretation of information, white matter transmits that information throughout the body using the nervous system.

- *How does it work?*

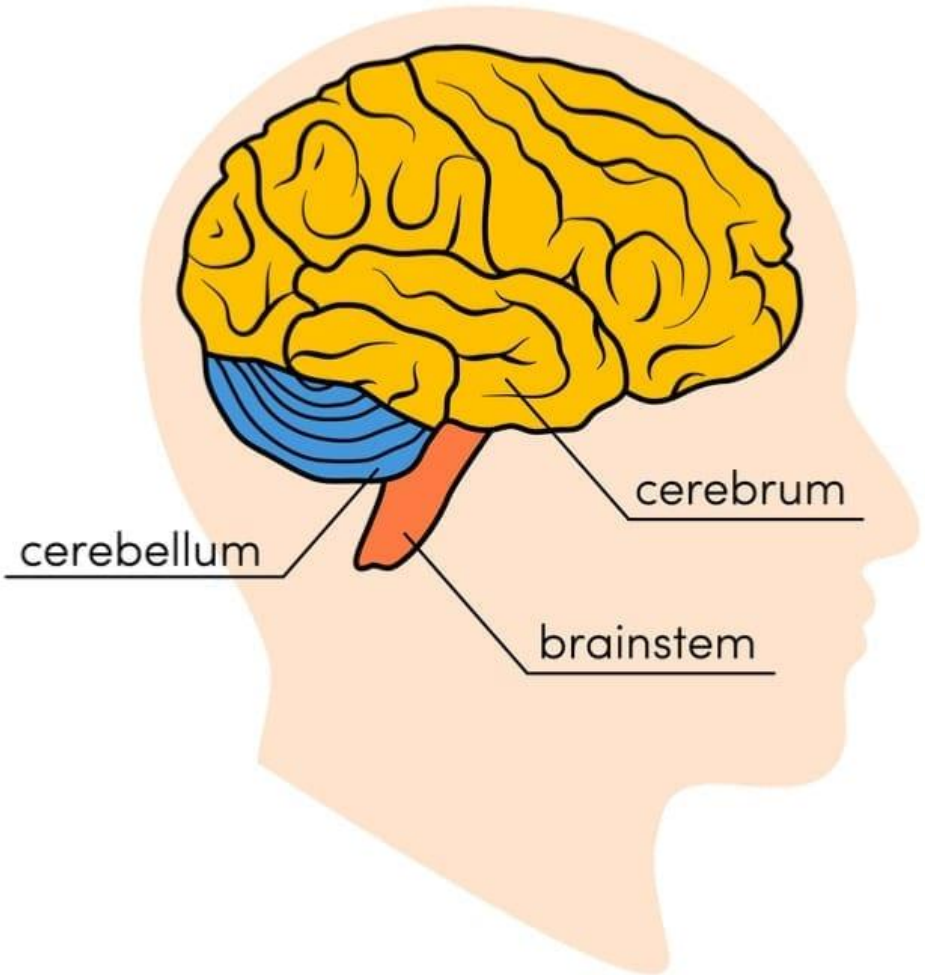
Explained in very simple terms, the brain works through the communication between different neurons. This communication is achieved through the sending and receiving of chemical substances and electrical signals between nerve cells in our body. These chemicals act as messages

so different chemicals mean different messages. There are many different chemicals impacting the brain on different levels and in different ways, for example some chemicals make you feel tired or make you feel pain. A lot of messages only happen in the brain, but some are relayed through the body with the spine's help.

- *The brain's main parts and what they do*

To go into further details, our brain can be divided into 3 main big parts each containing different areas serving diverse functions.

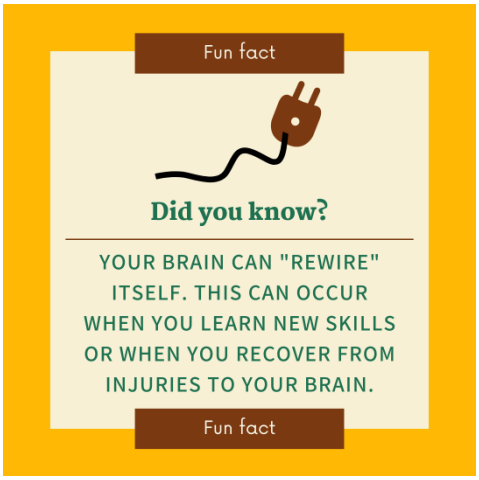
These main parts are called the cerebrum, the Cerebellum, and the brainstem or also called Encephalic trunk.



The human brain : https://blog.mindvalley.com/cerebrum-vs-cerebellum/

Cerebrum

The cerebrum is the largest part of the brain, it consists of grey matter on its outside and white matter at its centre. Its purpose is to start and handle conscious thoughts and actions. The areas within it specialize in certain domains like language, behaviour, sensory processing and more. For its entirety to function, the brain works as one entity applying the different areas of the brain to work together. This means that the cerebrum also includes some parts of the cerebellum.



These "conscious" actions include different elements that require thinking like:<

- **Five senses:** Here everything your senses take in gets managed and processed.
- **Language:** Your ability to read, write and speak are also controlled by the cerebrum
- **Working memory:** The working memory is a very widely used word used to refer to a kind of short-term memory.
- **Behaviour and personality:** The frontal lobe, which is a part of your cerebrum allows the things - that you might later regret to have said or done - to be filtered.
- **Movement:** As self-explanatory as the word movement is, this is exactly what your cerebrum does. Some areas of it send "conscious" signals telling muscles what to do when they're needed.
- **Learning, logic and reasoning:** When different tasks such as puzzling a problem out, making plans of action or learning new skills need to be accomplished different areas of your cerebrum work together.

Cerebellum

While the cerebrum is the part of the brain that controls conscious thoughts and actions, the cerebellum is a much smaller part of the brain sitting at the bottom and in the back of the brain. Its function is to coordinate and regulate a very diverse range of functions and doesn't only process in your brain but also your whole body.

But what precisely does it do then?

When researchers started analysing patients and animals with damaged cerebellums over 200 years ago, they found that those beings had trouble keeping their balance while walking or even standing and/or that they had difficulties reaching for objects because their hand would not react

as they'd like it to react. Almost as if their body was not listening to them. Concluding from these experiences, they thought that the cerebellum's function was to coordinate muscle movement.

Although the researchers were correct on this one, coordination of the muscle movements is not it's only purpose. Time had proven that the cerebellum was way underestimated and that it serves to way more functions than only coordination of muscle movement. In fact, research had proven that the cerebellum also helps with learning new words or skills, judging the size and distance of objects and it even helps with the sense of timing. For example, people with a damaged cerebellum are less precise, when trying to repeatedly tap their fingers. They'll often tap too soon or too late from beat to beat.

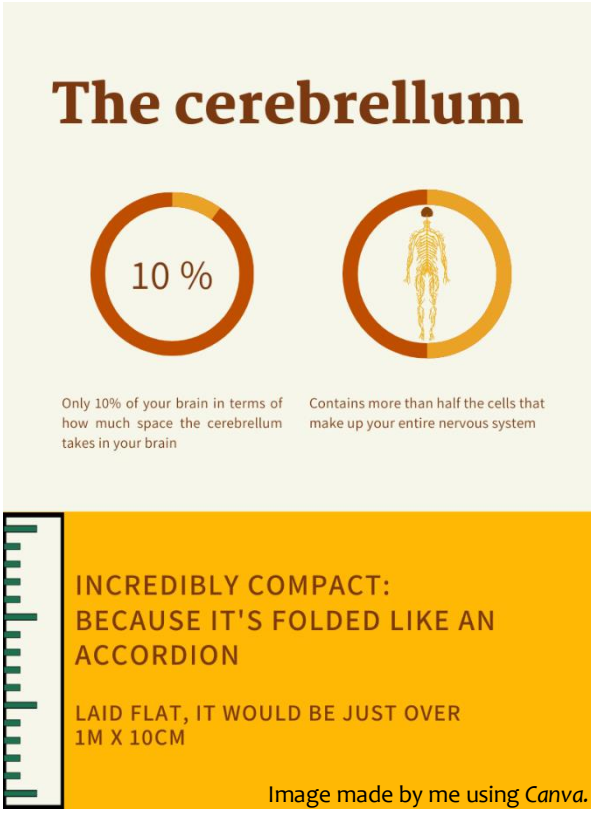


Image made by me using *Canva.*

To prove those theories, experts nowadays use different technologies to measure brain activity in different areas of the brain while accomplishing different tasks. While doing certain tasks, the brain is more or less active in different areas of the brain. These modern methods also showed that the cerebellum plays a role in emotions and the way a makes decisions.

Brainstem (Encephalic Trunk)

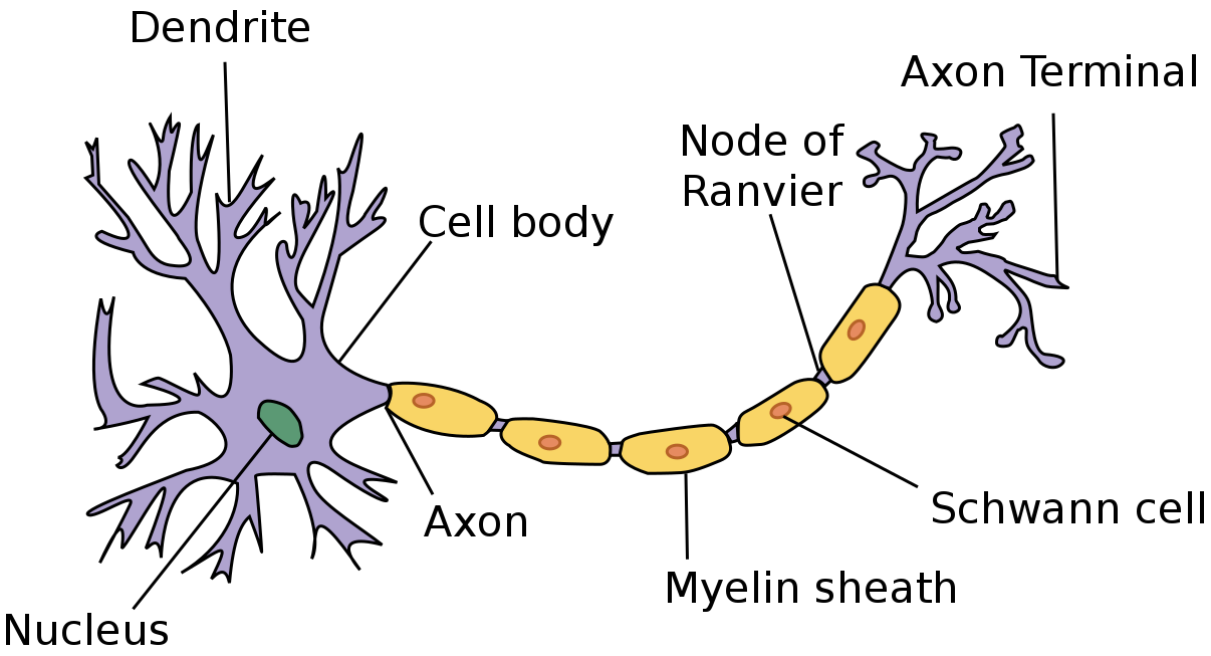
The brainstem is the part of the brain connecting the cerebrum to the spinal cord and to the cerebellum. It constitutes of three sections in descending order: the midbrain, pons and medulla oblongata. The brainstem is part of your central nervous system and connects the brain to the spinal cord. It sends messages between the brain and the body and helps coordinate the messages. It is involved in regulating your balance, blood pressure, breathing, facial sensations, hearing, heart rhythms, swallowing, sensations and taste.

Furthermore, the brainstem contains a so-called reticular activating system (RAS). The RAS are cells carrying electrical signals and chemicals through the brain, helping to control your sleep and wake cycles. Another feature is to help you stay alert and attentive to your surroundings.

Neuron anatomy

Estimates vary but today's neuroscience suggests that our brain contains around eighty-five billion - 85 000 000 000 neurons. Neurons are also called nerve cells. As already mentioned, these nerve cells are the primary functional unit of our brain. But how do they work precisely?

It is important to know that neurons exist in different shapes and sizes, but the following image shows a general image of a neuron as most of the people know it. This is also the way a lot of textbooks will visualize a neuron.



The neuron: https://teachmeanatomy.info/the-basics/ultrastructure/nerves/

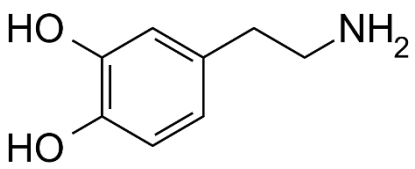
The structure extending from the left-hand side of the neuron are so called dendrites (as seen in image above). This is where neurons receive most of their information. This information is picked up by receptors located on the end of these dendrites in form of chemicals called neurotransmitters. When these signals get picked up by the dendrites, electrical changes appear. In the synapse gaps signals are passed on chemically. Once the neurotransmitters (chemicals) have reached the other nerve cell, the chemical signal turns back into an electrical signal (by shifting the internal and external ion concentration of the nerve cell) which is then interpreted in the nerve body before the information then is put together at the axon hillock. In other words, when the signal that comes from the dendrites, is strong enough it gets relayed to the axon. At this point the signal gets called an action potential. This action potential flows through the axon which is covered by so-called myelin sheaths. They are made of protein and fatty substances and prevent the signal from degrading, they also help speed the impulses – the electrical signals - up. The last step for the action potential is the axon termina or synaptic buttons. Once the signal has reached the axon terminals, it can trigger the release of neurotransmitters – in the next synaptic connection.

After the signal has passed through one neuron it will spread through the brain, because each neuron is connected to another neuron. In short, one neuron's dendrite is connected to another neuron's axon terminal through a synaptic connection. This is how billions of neurons form the entirety of this network called the brain.

The affected neurotransmitters

Dopamine

Different substances have different effects on the brain, but if there is one neurotransmitter released by a very big majority of drugs it is something called dopamine. Dopamine is often misunderstood and perceived as something that makes you happy which is not totally wrong but let me explain.



Even though dopamine plays a role in allowing you to feel pleasure, it also plays a big role in satisfaction and most importantly motivation. Examples of your brain releasing surges of dopamine is for example, when you have just achieved one of your goals and you get that feeling of pleasure. Rather ironically, it's already been released before you even just started that given task.

In fact, dopamine is the main neurotransmitter responsible in feeling motivation. This means that dopamine gets released when we think about doing something we like in order for us to get up and proceed to it. Then while proceeding with a task, surges of dopamine continually get released in our brain telling us to continue. The message which dopamine shouts to our brains is essentially "I want more of this". It bridges the gap between the expectations and the experience.

This means that dopamine also gets released as a reward. After doing something that requires effort your body rewards you by releasing this neurotransmitter causing a feeling of pleasure. Here the reward only gets released when the experience lives up to your expectations. Other examples of such moments where dopamine gets released are when you do sports, after a good learning session, eating food and also when you have sex, during an orgasm. Let's go into further details.

During an orgasm a series of different hormones and neurochemicals are released and one of these turns out to be dopamine. This is simply your body rewarding you for reproducing - or at least that's what it thinks you're doing...

Dopamine, a double-edged sword!

Even though dopamine plays a role in how good you feel, more dopamine does not mean more happiness. This is because dopamine is a double-edged sword. And a very sharp one. The reason addictions take place is because of too big a rush of dopamine. Because on one hand dopamine makes you feel good and on the other hand it makes you want more of what you're doing. Thus, consuming substances which have the effect of dopamine release can create dependency. Your brain will urge more dopamine release, and it will physically and mentally force you to take more and more of what previously released that major dopamine rush by making you feel excruciating $pains and other undesirable effects. But that will be talked about in further details later.

One factor that makes dopamine even more dangerous, is that your brain will never be satisfied with the amounts of dopamine it gets, because it will always want more and more of the pleasure coming with it. As I mentioned earlier, dopamine is what makes you want more of something. Put

into a more practical sense, when you eat chocolate, your brain will release dopamine. On one hand this dopamine release acts as a reward which means that you'll feel direct pleasure eating this piece of chocolate. But on the other hand, dopamine will make you feel a need to consume more chocolate. As long as dopamine is released your brain will want to release more of it. So you'll want to eat more and more chocolate.

This is dangerous because your brain will build up a resilience to dopamine, which means that the amounts needed to satisfy will grow. Since a lot of substances that cause the release of huge dopamine doses such as recreational drugs are fatal at certain doses, their abuse can in many cases lead to deadly overdoses.

Of course, this should not be taken lightly, furthermore something that hasn't been talked about yet is how your body needs dopamine to do almost anything. In fact, malfunctions in the brains reward system (the reward system is the part of your brain that is related to reward) are associated to one of the brain's most prominent human neurological disorder, Parkinson's disease. This is because the release of dopamine is essential to your ability to move. It does not only tell you to eat more chocolate, but it also tells your muscles to contract and recontract. Other domains your body needs dopamine to work include:

- Attention
- Learning
- Memory
- Sleep and arousal
- Mood
- Lactation
- And of course, most importantly pleasurable reward and motivation

On top of that, dopamine plays a role in different areas of the body like causing the blood vessels to relax. All of this being said, it should be pretty clear that addictions are associated with high levels of dopamine, but what does low dopamine levels mean? Diseases like attention deficit hyperactivity disorder or also called ADHD, the Parkinson's disease and the Restless legs syndrome are associated with low dopamine levels. There is also one very known disease that is associated to both high and low levels of dopamine which is Schizophrenia.

In conclusion, dopamine is a neurotransmitter involved in a lot of different areas of your brain. Although essential to our living, if not handled properly it is the reason our bodies (and minds) can get addicted to substances related to dopamine release and different diseases can occur as a consequence. It makes the line between pleasure and addiction a fine one.

Serotonin

Another neurotransmitter that is important to acknowledge is serotonin. This neurotransmitter is often referred to as a mood regulator. It's also involved and influences several other things in our body that include happiness, regulating body temperature, sleep, sexual behaviour, hunger and memory and learning.

When released, it flows into the blood circulation. Serotonin cannot be produced by the body but must be acquired through the foods consumed. Because it's made from tryptophan, an essential amino acid, your body can't produce it itself.

The reason this neurochemical is called a "mood regulator" is because when it is at normal levels you feel more focused, emotionally stable, happier and calmer.

Serotonin also plays a big role in the way your body processes food, which is the reason why much of this chemical is found in your intestines. It helps control your bowel function and plays a role in protecting your gut. During eating serotonin gets released which helps reducing appetite to get a sense of fullness. The way it can protect your gut is by increasing serotonin release to speed up your digestion in case of consumption of irritating food or toxic products. Another function, or rather consequence of serotonin release is nausea. In short terms when this chemical is released faster than your body can digest it, a feeling of nausea and vomiting occurs.

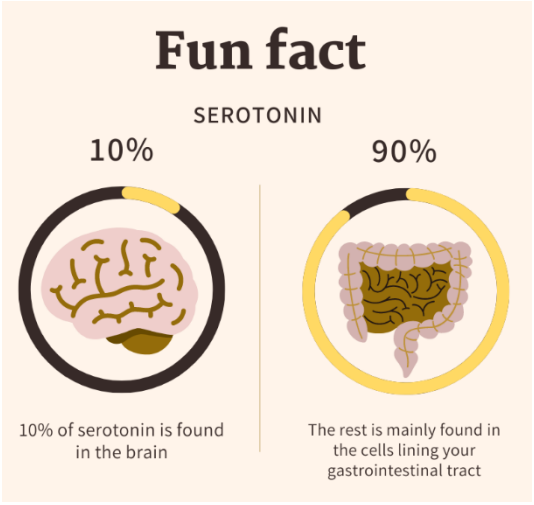
In conjunction with dopamine, serotonin plays a role in how much and how well you sleep. It takes part in regulating your sleep-wake cycle since it is a main component needed to make melatonin (a hormone that regulates your sleep-wake cycle).

When wounded, serotonin comes in handy too, since its capacity to narrow tiny blood vessels helps to form clots, being an important step in the process of healing.

Combined with dopamine, both serotonin and dopamine affect your desire for sex.

Too high levels of serotonin in your guts may sometimes be associated to weak bones. In accordance to that, bones are more likely to fracture which can go as far as to cause osteoporosis.

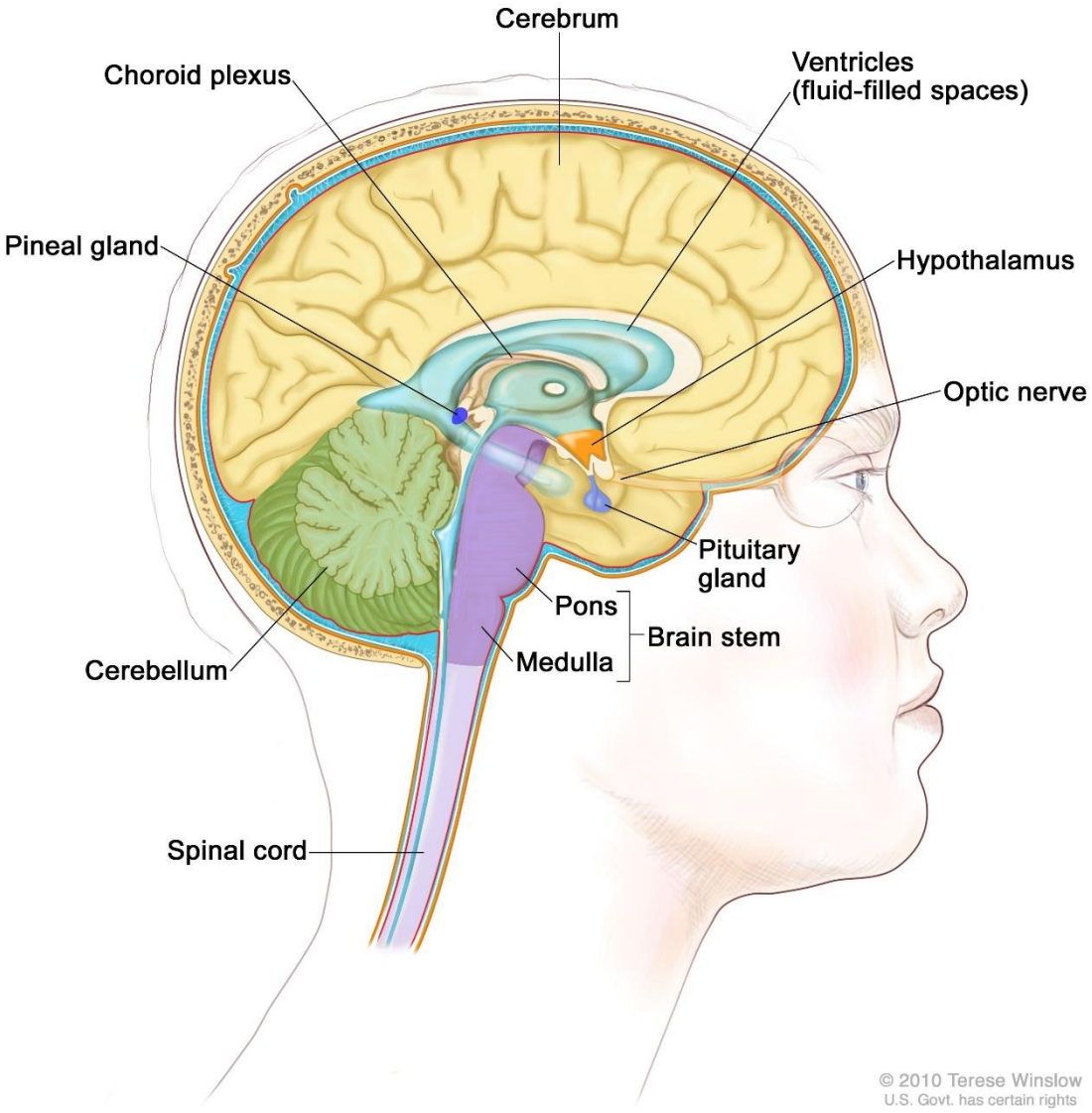
Disorders often associated with low quantities of serotonin are depression, high amounts of anxiety and other mood disorders. This is the reason a lot of medications used to treat these types of disorders target ways to increase your level of serotonin in the brain. These almost work the same way than many drugs aiming to reduce feelings of nausea and vomiting do, targeting specific serotonin receptors in your brain.



Endorphin

Hormones that often occur when talking about drugs are the endorphins. These are released to help relieve pain, reduce the stress and generally to improve mood.

These neurotransmitters are mainly produced in two areas of your brain. One is the pituitary gland and the other one is your hypothalamus. When secreted these neurotransmitters attach to your brain's reward centres also called the opioid receptors to then carry signals across your nervous system.



Pituitary gland and hypothalamus: https://www.cancer.gov/publications/dictionaries/cancer-terms/def/hypothalamus

When dissecting the word endorphin, it is easier to understand its function. One part of the word comes from "endogenous" and means "within the body", and the second part of it comes from "morphine", an opiate pain reliever. When all of it is put together endorphins are natural pain relievers.

I refer to endorphins in plural, because there are more than 20 types of endorphins in your body. The so-called "Beta-endorphins" are the endorphins involved in stress relief and pain management, whose effects are stronger than morphine's effects.

Endorphins work by essentially switching off your brain's ability to feel pain. They block nerve cells that receive pain signals and thus interrupt your body's pain signal before it can reach the brain.

Dopamine and endorphins intimately work together, since when the endorphins bind to your opioid receptors, dopamine gets released and give you a sense of pleasure. In some cases, the amounts of dopamine released are so high and intense that they make you feel euphoric.

The easiest way to release endorphins is by exercising. In fact, the "Runners High" is simply your body secreting large amounts of endorphins to stop your muscles from aching. Combined with dopamine it makes you feel that euphoric experience. If repeated, these emotions can be addictive. Although many people feel it through running, loads of different activities release endorphins. Active activities include:

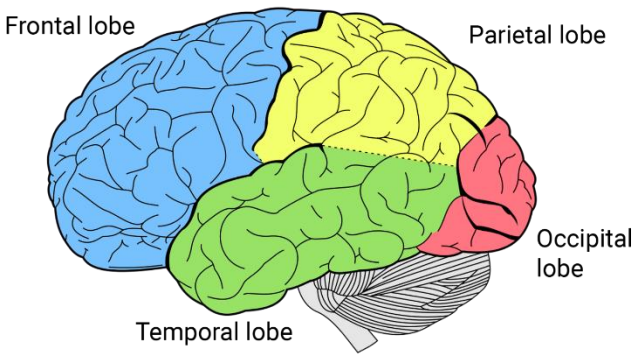
- Swimming
- Dancing
- Hiking
- Sex
- Meditating

And more passive ways to release endorphins include:

- Acupuncture
- Massage
- Eating
- Listening to music

Having low amounts of endorphins can lead to depression, anxiety, unusual body aches and pains, sleep issues , impulsive actions and addictions.

The Teenager's brain: how is it so different from an adult brain



The teenage years are a time of immense change, both physically and mentally. One of the most notable changes during this time is the malleability of the teenage brain. Teenagers' brains are still developing, and this development continues until their mid-20s. This malleability means that teenagers are highly responsive to experiences and information and can adapt quickly to new situations. This is why they are often described as being "sponges" for information, and why they are able to learn new skills and information so quickly.

Writing this chapter, my goal is to write about a teenager's brain and how it works, in order to introduce a base knowledge needed to understand the next chapters.

An underdeveloped frontal lobe

The easiest way to go about this is to understand how the brain develops into its "final state" of adulthood. The reason I put final state into quotes is because the brain is always changing. Even as

an adult. Although this is true, let's put it like this: the teenage brain changes more and not in quite the same way as the adult's brain. In fact, translated into science "going from a boy to a man" means the process of the brain developing. To dive head first into this chapter, let's start with the cerebrum. In teenagehood, the part of the brain developing the most is the cerebrum. More specifically, the frontal lobe. The brain develops from the back to the front. This means that in the teen years, the brain is least developed in its region of the prefrontal cortex. T

Unlike the prefrontal cortex' slow development the part of the brain called the limbic system[1] develops faster, which causes an unbalance between those two regions of the brain. Considering that the frontal lobes are responsible for taking the right decisions and thinking about consequences and the limbic system for instant gratification, this alone could explain a lot of the irrational and impulsive choices teenagers tend to make and why they might feel emotionally so unsteady.

the teen brain developing from the back to the front: https://nida.nih.gov/drug-topics/adolescent-brain/longitudinal-study-adolescent-brain-cognitive-development-abcd-study

"Sponges" for information?

Another thing that sticks out during adolescence is a brain region called striatum. Because it's connected to the limbic system, when given a reward, this region goes off and releases dopamine. The striatum coordinates different aspects of cognition including motor and action planning, decision making, motivation reinforcement and reward perception. While every human being has a striatum, the adolescent's one's are "way" more sensitive. This means that when given a reward, teenagers will release a lot more dopamine than adults.

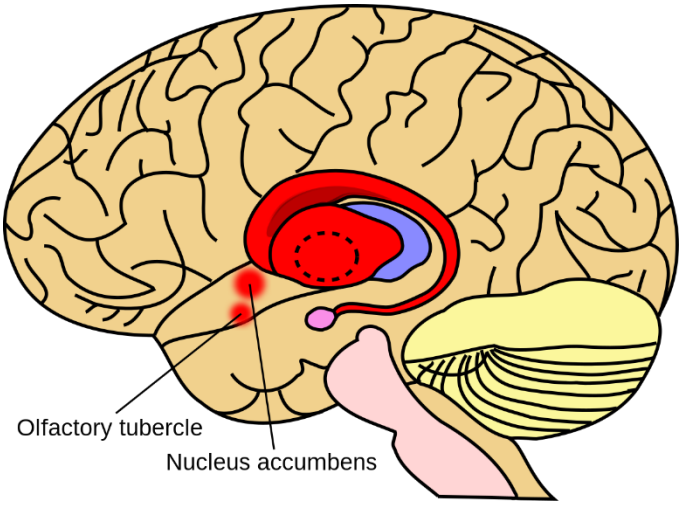
Let's take this into another scenario. Imagine a teenager learning vocabulary. Every word he gets right his striatum goes off and releases dopamine. Of course, the same thing happens with adults or else they would not be able to learn anything new. However as mentioned before, in the teenager's brain, every answer they got right releases a lot more dopamine than in the adult's brain. This leads to adolescents learning faster than adults.

Olfactory tubercle: https://en.wikipedia.org/wiki/Olfactory_tubercle

[1]The limbic system is the part of the brain involved in our behavioural and emotional responses, especially when it comes to behaviours we need for survival: feeding, reproduction and caring for our young, and fight or flight responses.

Long story short, an adolescent's brain is not just a fully developed brain with less miles on it than an adult's brain, but it is actually work in progress. This is a delicate process and disrupting this could mean life-long side effects.

Thinking about it even without neuroscientific knowledge, all of this makes sense, however stupidly enough so many teenagers autodestruct their brain and actually cause those undesired side effects themselves. There are really a lot of factors that could be considered dangerous to the brain proper development going from undesired accidents to voluntarily taking drugs. Even playing some sports can damage the brain quiet a lot. The perfect example would be American football.



Although all of this is true, there is one thing that preoccupies a lot of people, adults as well as teenagers. Something that has been known to rip families apart, demolish lives but also to wreck brains. This is especially true for younger brains. Drugs. Not the pharmaceutical drugs but the recreational drugs. Alcohol, cannabis, and hard drugs.

Even though we all know that drugs are bad for you, people still take them, and they are getting accepted more and more by our society, even by teenagers. This leads to me thinking that there is somewhat of a misconception about drugs in our society and about the damage they do to our brains.

Our brain on drugs

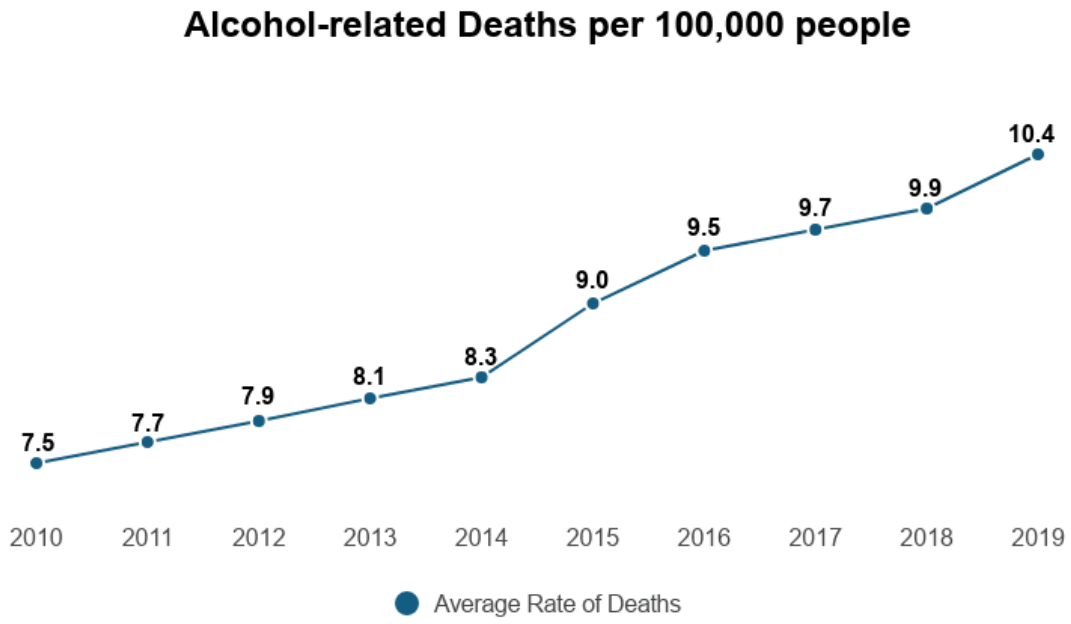
As I said in the introduction, writing this research is my attempt to illuminate you of the dangers drugs bring along, besides (all) the pleasure they provide. Especially for the younger public. You've finally made it to this research's purpose. The next chapter is going to be about how recreational drugs mess with your brain and why you should try to avoid their consumption as much as possible.

THE PSYCHOACTIVE EFFECT OF DIFFERENT SUBSTANCES

Alcohol

With alcohol being a so-called "social drug" largely accepted in our societies, even encouraged by some cultural beliefs, its dangers are often neglected, not taken seriously or even misunderstood. While its consumption can be seen at multiple occasions throughout the day, alcohol remains a major problem. Its effects are detrimental to every aspect of our lives, but its dangers are especially brought to light when consumed at a young age. I will analyse the different aspects in detail later on.

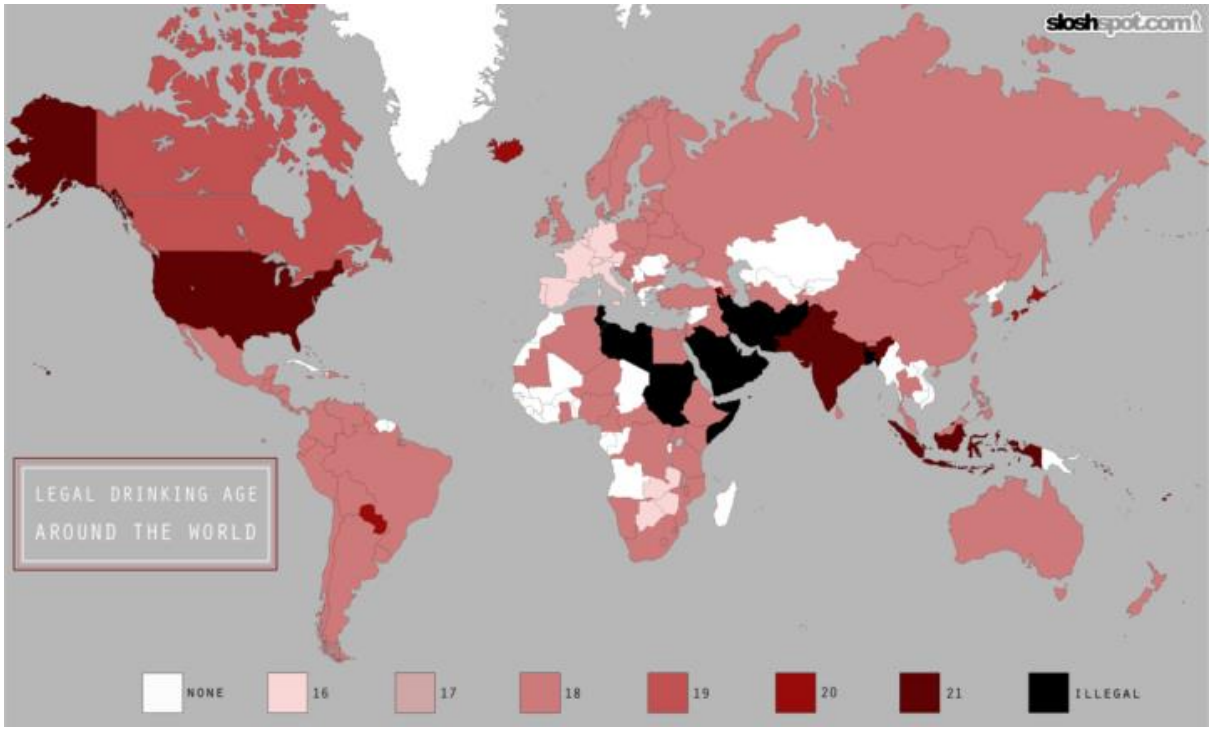
"If recreational drugs were tools, alcohol would be a sledgehammer" wrote psychiatrist Aaron White in a paper for the *National Institute on Alcohol and Alcoholism* in 2004. Quite sadly, a lot of Luxembourgish residents get sledgehammered quite often. In fact, one of Eurostat's studies suggests that one in three residents in Luxembourg gets drunk "at least once a month" which puts Luxembourg number 2 in EU's top three countries where so-called "heavy episodic drinking" is most frequent. Other statistics related to drug abuse in the United-States show that the number of people that die from excessive alcohol use range from ~ 70 000 – 140 000 annually. Alcohol is the third-leading cause of preventable death after tobacco and poor diet and exercise choices. These numbers alone should be enough to prove alcohols dangers but to further prove my point I'll follow with more statistics. In fact, in America more than 6% of adults have some kind of alcohol use disorder. Which makes it 1 in 12 men and 1 in 25 women. And most shockingly, around 623 000 people between the age of 12 and 17 reportedly have alcohol use disorders.



Alcohol related deaths per 100.000 people: https://drugabusestatistics.org/alcohol-related-deaths/

This widely spread alcohol drinking habit is of course partly the result of novelty-seeking, poor judgment, and risk-taking behaviour but some social components play a huge role too. If two cohabiting teenagers go out and one of them downs litres of beer every night, the likelihood that the other roommate starts consuming big amounts of alcohols will rise. In Frances Jensen, MD and Amy Nutt's book "*The Teenage Brain*" they mention a study suggesting that students tend to pattern their drinking "on the amounts they perceive peers to be consuming". This supports my earlier statement. In another study researchers found that college students consistently overestimate the amounts other drink. This reinforces the previously discussed social effect, since it means that even if that roommate only drank half a litre of beer, his friend will think he drank more and accordingly consume even larger more alcohol himself.

"Alcohol use disorders" sound like no fun and a pretty extreme statement which is the reason I want to talk about the sources I use and what the author defines by this disorder. First, as we know the United States alcohol use laws are quite strict. *The Minimum Legal Drinking Age* (MLDA) is 21 years whereas in most of the other countries the MLDA is 18 or even lower. This totally changes the way people see and treat alcohol. I am not going into further details about the politics and history behind this decision because that is not the purpose of this research.



Legal drinking age around the world (https://flowingdata.com/2009/03/27/legal-drinking-age-around-the-world/)

To get back to the sources I use, they dedicated a paragraph to their definition of an "alcohol use disorder". I quote: "Alcohol is a problem when it causes problems". In short, according to the author, alcohol consumption turns into a disorder when things like being late to work because of a hangover, when straining your relationships with loved ones and in extreme cases when things like losing control over oneself and becoming violent. This means that alcohol becomes a real problem in one's life once an addiction starts to occur.

Enough numbers now, let's get to the reasons why alcohol is such a great danger to our society. The first things that come to mind when thinking about alcohol is addiction. Alcoholism.

What are the steps to alcoholism?

Stage 1

The very first stage of alcoholism starts while simply experimenting with alcohol. This stage is commonly seen in adolescents and young adults. They'll try different kinds of alcoholic drinks and often test their limits. This is where binge-drinking comes into play. One is considered to be binge-drinking after consuming four or five drinks in one session. In a lot of cases, these amounts are greatly exceeded. Especially at parties where drinking is the main activity.

A lot of people think that binge-drinking on rare occasions is safe, but alcohol is a lot more dangerous than one might think. When consumed in large amounts alcohol can lead to coma and if not handled with proper medical attention this coma could lead to death. According to the pediatric researcher Nico van Der Lely of the Reinier de Graaf Hospital in Delft, an ethylic coma is comparable to violently getting hit by a baseball bat. Even if one did not drink enough to fall into a coma there is a risk that a dependence to alcohol starts to develop.

Stage 2

The second step towards alcoholism is when the concerned person starts to regularly drink going from once in a while to every weekend. As time continues this becomes a habit and your happiness will become progressively more dependent on alcohol. You will link certain moments of your life such as going out with your friends to alcohol and won't be able to enjoy these without one or several alcoholic beverages.

Stage 3

Step three is when you start to feel the impact of your uncontrolled drinking on your everyday life. This is where the term "problem drinking" gets used. This step can lead to a development of several problems. These could be experiencing legal troubles as a result of one's drinking, being more likely to drink and drive and four other specific social changes often occur in problem drinkers. These are: relationship issues, decreased social activity because of erratic behaviour, sudden change in friends and difficulties conversing with strangers.

Stage 4

Step four is not quite addiction yet. As a matter of fact, alcohol has two sides. One is dependence and the other one is addiction. Dependence always occurs before addiction and this is the stage where you get emotionally attached to alcohol and its effects. It has taken over your routine and you know its affect but can't control your consumption. At this stage your body builds up a certain tolerance and the amounts you need to feel alcohol's effect will grow. This is where your body gets increasingly damaged.

This is where another problem will occur. Withdrawal. Once sober several symptoms like nausea that is unrelated to a hangover, body tremors, sweating, , a racing heart, severe irritability and trouble sleeping will appear in your life.

Stage 5

The final stage is addiction. Drinking is no longer just for pleasure but your need to drink alcohol is physically and psychologically rooted in you. Your body needs alcohol to be able to work. It physically tells you to drink alcohol through literal pain and compulsive behaviours in case of its absence.

The effects of alcohol other than its addiction risks

Alright, addiction is bad and that is a known fact, but heavy alcoholism is still on the rarer side of things, which means that not a lot of people are going to feel concerned. Although alcoholism is a huge problem, alcohol isn't only bad for you in such extreme cases and this is often forgotten or trivialised.

In fact, as mentioned before, when going out a lot of teenagers drink more than just one alcoholic beverage. But what can even just one night of binge-drinking do to your brain? On a neuronal scale, what does alcohol (EtOH which stands for ethyl alcohol) do to your neurons?

When drinking too much, a lot of people experience memory losses. Alcohol blocks glutamate receptors that are needed to build new synapses. In simple words, these memory gaps occur when

alcohol temporarily blocks the transfer of memories from the short-term to the long-term memory storage. This is also called the process of consolidation and it happens in your hippocampus. These gaps are one of the more short-termed effects of alcohol. However, these receptors being blocked can also explain the fact that many heavy drinkers have significant memory problems. Having a blackout does not always mean that your brain has been damaged, but as mentioned before long-term brain damage is clearly a side effect of alcohol use. Funnily enough, even if the teen's brain is more malleable, this does not mean that it recovers faster from alcohol than the adult's brain. In fact, it takes longer for a teen's brain's glutamate receptors to recover their function than for an adult's brain.

The long-term brain damage that alcohol can do your brain is where it gets scarier. In fact, studies are finding more and more side-effects alcohol can cause to teen brains. Effects like damage to cognitive, behavioural, and emotional functioning. Attention deficit, memory problems, depression and a reduction in goal-directed behaviours are the more direct effects that alcohol can cause.

This is due to the alcohol's capacity to not only destroy neurons in our hippocampus, but it also impair its ability to produce new ones. This was discovered in researchers *Michael Taffe's* study which involved monkeys who were given a certain amount of alcohol which was equal to a strong cocktail every day for an hour, over a period of eleven months. It was found that the monkey's hippocampus did not only reduce the number of its neurons but also the amount of its neuronal stem cells. Stem cells are responsible for generating new cells, since they are able to divide into more mature cell types. After just 2 months of drinking the monkeys had already started losing neurons and after 11 months their hippocampus had lost more than half of its production rate of stem cells and what was left seemed to be damaged.

Cannabis

In recent years, there has been a significant shift in the societal perception of cannabis. As more and more countries and states legalize its use for both medicinal and recreational purposes, cannabis is becoming increasingly accepted as a normal part of modern life. However, this normalization of cannabis use can lead to a dangerous misconception that it is a harmless substance, especially among teenagers.

Today Luxembourg's most used drug is cannabis. It can even be prescribed by doctors so why should it be as dangerous as I say?

Consuming cannabis as an adult is not in itself a problem, or at least its side effects are not so detrimental. This however changes when we talk about a teenager consuming cannabis. In fact, a study published in "*The lancet psychiatry*" called: *Association of cannabis potency with mental ill health and addiction: a systematic review*, found that early systematic consumption of cannabis (more than twice per week) impacts later probability of psychosis and other psychiatric conditions. Smoking pot as a teenager has permanent consequences on systems related to mood regulations and on the ability to organize and to execute one's thoughts and plans. In this chapter I am not going to talk about marijuana's physical's side effects like the fact that smoking is bad for your lungs, I am rather going to focus on the mental and neuroscientific side of this drug. Thus, asking and answering questions like: how does it work and why is it bad for you.

How does pot get you high?

To get started, let's talk about what it is that makes cannabis so dangerous to the teens brain. The so-called molecule of THC or Delta-9-tetrahydrocnnabinol is cannabis' primary psychoactive cannabinoid. What is a cannabinoid? Well – as you may already have guessed - this is a type of chemical in marijuana that causes drug-like effects all throughout the body. In some parts of your brain, your neurons have specialised cannabinoids receptors. Although a variety of tissues in our body like the brain, fatty tissues, and immune cells produce small quantities of endocannabinoids (endocannabinoids mean that these get naturally produced by our brain – in small quantities), smoking marijuana greatly enhances the influx of these circulating in our brain.

You may be asking yourself why we naturally produce endocannabinoids and why those don't negatively affect our brains. First, not every cannabinoid's purpose is to make you feel a high. In fact, these are molecules, which purpose is to contribute to some of our body's key functions like energy balance and appetite stimulation. Secondly, THC is one of the stronger cannabinoids. Given the high concentration of THC that is found in most cannabis strains, this leads to unusual brain activity, causing a high.

On a microscopical level, after inhalation the THC passes from the lungs into your body's blood. The blood then delivers the cannabinoid into the brain. In the brain, the molecule acts on specific cannabinoid receptors. These receptors are found in areas of the brain associated with concentration, thinking, time perception, coordination, memory, and sensory pleasures.

To understand what happens to your neurons on a microscopic scale, we need to recall the neuron's anatomy. After neurotransmitters get released from one neuron to another, the neuron

"takes a break". This means that for a short period, neurons temporarily get unresponsive to prevent them from overreacting or being too dominant which could create an unbalance in your brain. That's the way your brain regulates its activity to function in a calm and controlled manner. However, cannabinoids interrupt this regulation in some parts of the brain which lets your neurons fire more frequently and in consequence to magnify your thoughts, perception, and imagination.

Smoking also releases dopamine and norepinephrine (adrenaline), which on one hand makes marijuana an addictive drug and on the other hand gives you a sense of euphoria and relaxation. The study published by Hasin and colleagues talking about the relevance of marijuana use disorders in the United States between 2001-2002 and 2012-2013, found that around 3 in 10 people who use marijuana have a cannabis use disorder. A different study estimated that "people who use cannabis have about 10% likelihood of becoming addicted". When smoked, cannabis is in most cases mixed with tobacco. This increases not only the damage smoking pot will do to your body, but it will dramatically increase your chances to develop an addiction. Researchers found that, ironically, in a lot of cases your brain will not develop an addiction for weed, but rather for the nicotine in the tobacco. However, it will subconsciously link both cannabis and tobacco, leading you to also develop an addiction for weed. The steps to addiction are very similar to those of alcohol. Today, weed is getting more and more dangerous, because high THC concentrated strains are getting more accessible due to different factors. The higher the amounts of THC found in cannabis, the higher the dangers not only of addiction but also to the brain.

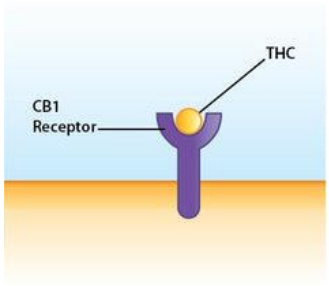
The adrenaline release following pot consumption s regulates pain and generally enhances experiences like eating or listening to music. Although these effects all sound desirable, aside from its detrimental effects on the undeveloped brain, marijuana can in certain cases cause extreme fear, paranoia, and anxiety. Another reason weed is dangerous is because it is a so-called gate-way drug. This means that consuming cannabis will potentially motivate you to try other harder drugs. There are a few reasons why this can be true. Since weed is often smoked with friends, the individuals you associate with might change, and you could gravitate towards those who smoke more frequently and even consume harder drugs. Furthermore, another reason weed is considered to be a gateway drug is that you may enjoy its effects so much that you'll grow an interest toward trying new, stronger drugs. If this still isn't enough reasons, the possibility for you to "get bored" of weed's effects or that your brain has built up a certain resilience to it can encourage you to dive into more extreme drugs.

Alright, but why is it bad for the brain?

As we talked about earlier, THC dysregulates your brains activity by preventing your endocannabinoids to do their job which consists in regulating your neuronal activity. If I was to put my previous text into very simplified manners, I'd say that when you smoke pot, some regions of your brain go into a sort of unregulated hyperdrive leading you into a state like psychosis. This is the reason that when you get high, your brain dives into these deep thoughts, wandering from theme to theme. You perceive life from a different perspective. But other than its addiction risks, why would your brain working more than usual be bad? Why does smoking cannabis have long term side effects on your brain?

To get started it is important to understand how THC binds to our neurons. First, this molecule is thought to exert most of its psychoactive effects by binding to the so-called cannabinoid receptors that I mentioned earlier on. There exist two known cannabinoid receptors called CB1 and CB2. These receptors are so-called G-protein-coupled receptors (GPCRs). Don't lose me here, it is easier to understand than you'll probably expect. These GPCRs are simply receptors that are found on the cell membrane (the outer layer of a cell), that act like an "inbox for messages" – in this case the THC is the concerned message.

The problem with THC binding to CB1 receptors



These CB1 receptors are found all throughout our nervous system and CB2 receptors are primarily found on immune cells. Stefan Dheil, researcher and teacher at the University Leipzig claims that CB1 activation by THC in teenagers have been found to diminish the production of neuronal growth factor in neurons, thus interrupting the brain's development. THC is also known to affect other signalling cascades[2] involved in synapsis formation. Given that these factors both play an important role in the brain's development and in the neuronal conversion process during puberty, it is safe to say that THC interrupts the brains proper development and should be avoided at all costs during these times of precious evolution.

Moreover, THC affects long-term potentiation (LTP) which is a process by which connections between neurons become stronger with frequent activation. It simply is the scientific term that describes the way in which the brain changes in response to experience and is one of the mechanisms involved in the process of learning and memorising. This could explain why young heavy smokers very often have or develop problems memorising certain information and have trouble learning throughout their lives.

As if this wasn't bad enough already, I have some more bad news about cannabis for you. Researchers have found that schizophrenics have less white matter than normal people. Why am I telling you this? Well, yes, as you might have guessed, the same pattern is also seen in those who have been using cannabis on a regular basis during adolescence. Data reveals that the risk to develop schizophrenia is 2 to 5 times higher in people that have smoked chronically as a teenager than for people who haven't.

[2] A signalling cascade is an evolutionary-conserved mechanism that is used to amplify a signal, mainly consisting of protein kinases (MAP and MAPK)

Hard drugs

In the previous chapter, we explored the neurological effects of marijuana on the teen's brain and the risks associated with its use. While today it is a widely recognized drug, there are many other substances that can have even more severe consequences. Hard drugs are often more hidden in our society and not as widely recognized, which is why I want to dedicate a chapter to this topic. Despite this fact, their use continues, often with serious consequences. In this chapter, we will explore the different neurological effects of these hard drugs and the risks associated with their use. I decided to divide this chapter into a few different sub-chapters which represent a certain type of hard drug. I chose the 3 types of drugs that are heard of the most and I will talk about 1 to 2 popular drugs per sub-chapter. I'll go from party drugs like cocaine and ecstasy, to hallucinogens like LSD and magic mushrooms, to opioids like heroin and morphine, keeping every drug description relatively short and easy to understand.

Party drugs

The first category of drugs I want to talk about are party drugs. They are probably the hard drugs that teenagers get into contact with the fastest and most frequently. In my opinion the most known party drug is cocaine. It can be found in many movies; it's talked about in a lot of songs and is generally heard about quite often. This makes it my first choice of party drugs that I feel like is important to talk about and to raise awareness about. It is not as pretty of a drug as we think it is. It is quite the opposite. After cocaine I'll talk about ecstasy, because when I used to skate, that was the hard drug I heard about the most. Being a chemical drug it's components and side-effects are not so well known, thus encouraging me to write about it in order to inform as much people as possible and to spread awareness.

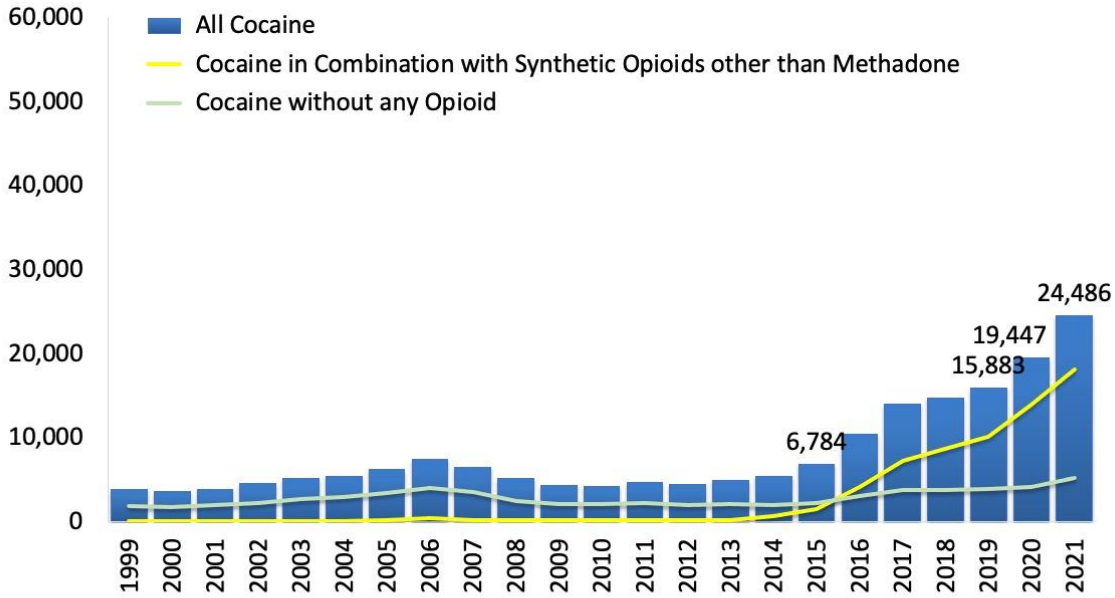
- *Cocaine*

Cocaine most often gets consumed in form of white powder that is inhaled or sniffed through the nose. It comes from dried leaves of the coca plant, that are found in South America.

Cocaine is a stimulant which means that when consumed, it causes a rush of energy, a state of higher alertness and a feeling of euphoria. It increases your heart rate along with some other sympathetic nervous system responses, which is a fancy term to name your brain's system to respond automatically to dangerous or stressful situations. Furthermore, cocaine is highly addictive because it's consumption drastically increases levels of dopamine, norepinephrine, and serotonin. In fact, in some cases one try is enough to develop an addiction. As we talked about in the first chapter, teenagers are more susceptible to develop addictions and get addicted a lot faster. This makes cocaine so much more dangerous for the younger public, since because the drug's very addictive nature creates an even greater risk of addiction in teenagers.

No surprise, cocaine has long-term effects if it is used as a teenager. Like with weed and alcohol, data proved us that early cocaine use changes brain structures involved in learning, memory, and especially reward. Another danger of cocaine is the risk of overdose. Since this drug increases the heart rate, its use can cause problems like strokes, cardiac arrests, and deadly arrhythmias. In fact, in the year 2021, in the US 24.486 people died from a cocaine overdose. As you can see on the graphic the numbers of deaths have increasingly grown from around the year 2013 to 2021. These numbers show how dangerous cocaine truly is.

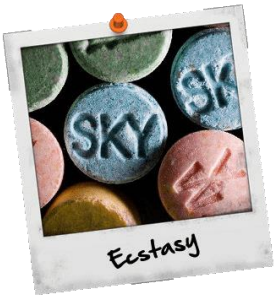
Figure 8. National Drug Overdose Deaths Involving Cocaine*, by Opioid Involvement, Number Among All Ages, 1999-2021



*Among deaths with drug overdose as the underlying cause, the cocaine category was determined by the T40.5 ICD-10 multiple cause-of-death code. Source: Centers for Disease Control and Prevention, National Center for Health Statistics. Multiple Cause of Death 1999-2021 on CDC WONDER Online Database, released 1/2023.

National drug overdose deaths involving cocaine: https://nida.nih.gov/research-topics/trends-statistics/overdose-death-rates

- *Ecstasy/MDMA*



Ecstasy, also known under the name of "MDMA[3]", "Molly", "Lover's Speed", and "XTC" is a stimulant too. Like cocaine, this drug is often consumed at parties, because it produces an energizing effect, distortes of your time perception and visual perception, and enhances enjoyment of tactile experiences. Like the other hard drugs I mentioned, MDMA makes you feel euphoric, but it also creates a feeling of closeness and empathy. Although it does not have the same effects on everybody, ecstasy is also by some used as a sex drug, being known for its ability to increase sexual arousal.

This drug can be found under a lot of different forms due to its chemical nature. Although usually consumed in the form of pills, it can also be swallowed in gel capsules or tablets. Additionally, to this, people sometimes snort it, and it can and even be smoked.

When consumed, MDMA triggers the release of disproportionate amounts of serotonin. Rappel: serotonin controls appetite, sleep, learning and mood. Along with serotonin, dopamine and norepinephrine get released which makes this drug addictive.

The problem with MDMA is that, since your body releases unusual amounts of serotonin, it also needs to destroy unusually large amounts of these chemicals. This means that after the ecstasy hit, you are left with a feeling of emptiness, because remember, serotonin is a mood regulator. If you don't have enough of it, you'll feel depressed. This also why the use of ecstasy can cause depression amongst teenagers, because it creates an unbalance in the natural serotonin regulation. As if this wasn't bad enough already, XTC destroys the endings of brain cells involved in serotonin, thus causing permanent brain damage.

Hallucinogens

Hallucinogens are a class of psychoactive drugs, causing your brain to go into altered states of consciousness, altering your thoughts, mood, and perception as well as other changes. This is perhaps the most complicated and confusing class of drugs, since a single trip, can entirely change the way a person sees, hears, tastes, smells or feels. They are also known for their capacities to change the way a person thinks and it also affects a person's mood..

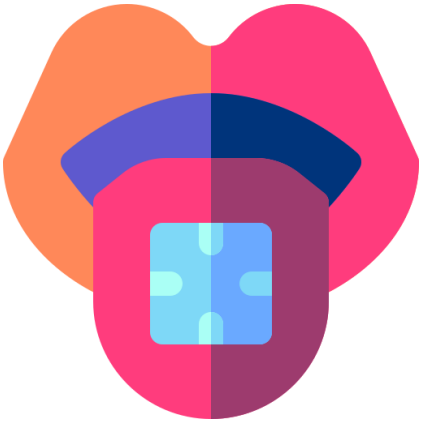
- *LSD/Acid*

Consumed in form of "tabs[4]", LSD is one of several famous hallucinogens. It affects different receptors such as dopamine, adrenaline, glutamate and serotonin receptors, especially the one named 5H2TA. The way LSD works is that when the molecule hits this 5H2TA receptor, it gets trapped and continuously makes it fire. To counter this, your brain "sucks" this 5H2TA receptor

[3] MDMA stands for MéthylèneDioxy-N-MéthylAmphétamine which is the same molecule as in ecstasy. Although I don't differentiate ecstasy and MDMA, ecstasy is the same molecule as MDMA, but chemically altered with additives like caffeine or amphetamine.

[4] A „tab" is a small paper square with pictures on them, that have been soaked in LSD. You place it on your tongue and wait for the LSD to hit.

into the cell to degrade the LSD molecule. This process takes up to 12 hours, meaning that a single LSD tap can get you high for around 12 hours.



LSD causes your brain to "rewire" and research has shown that different parts of the brain especially the occipital cortex responsible for vision get impacted. Funnily enough, even if this drug acts on dopamine receptors, it is not addictive. Thus, LSD has surprisingly been proven to be a lot less dangerous than other drugs like cocaine and heroin, to the brain as well as to the body. Another factor that is important to know about LSD is that it is not really possible to do a fatal overdose. Although this is true, it is extremely important to understand this does not make LSD a harmless or safe drug. When taking too large quantities of it, your brain struggles to decompose the LSD stuck in your 5H2TA receptors. This can cause you to have a bad trip, and to develop irrational fears, paranoia and panic attacks.

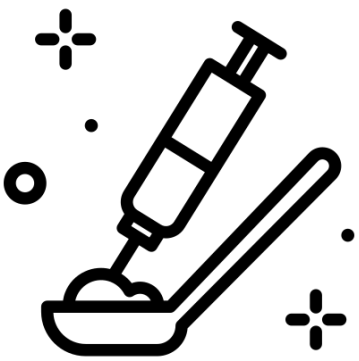
Today, there is still a lot left to be found out about this drug, since there is not a lot of research about it. I did not find any recent studies that talk about how LSD affects the teenager's brain, which explains the lack of information about this drug concerning this younger public. Although I couldn't find research about teenagers on LSD, I found some data that may show that in a near future acid could be used to treat diverse mental illnesses.

Opioids:

Originally, opioids are a type of medication also called narcotics that are prescribed to treat severe pains, containing the chemical of opium. Although opioids can be used in a legal context, they are also consumed as recreational drugs. Of all the opioids, heroin is the most known opioid, which is the reason I chose this drug as the next drug I want to talk about.

- *Heroin*

Being one of the deadliest and most addictive drugs worldwide, there is a lot to talk about. Being consumed by injection, inhaled by smoking or snorted, it is often times mixed with different drugs like methamphetamine or cocaine for an even better experience.



When consumed, the morphine found in the substance, connects to your neuron's opioid receptors, releasing dopamine… a lot of it. The heroin will slow down the user's heart rate and breathing rate creating a sense of euphoria. Like endorphin mentioned in the first chapter, morphine is a painkiller.

The problem with heroin isn't only how addictive it is, but your body's tolerance to heroin builds up very fast. This means that even after the first dose, your body grows a resistance meaning your dopamine receptors get less and

less affected, the more heroin you consume. Your body adapts. Now the same amount of dopamine won't produce as much pleasure as before. This means that you'll need larger and larger doses to obtain the same effect as in the previous trip. Considering that heroin can be fatal this can be life threatening. At a certain dose, your heart or your breathing will stop.

Once the user has realised what heroin is doing to his body and decides to quit, it is almost impossible. Your body gets used to having heroin in the blood and without it, diverse withdrawal symptoms like anxiety, nausea, and excruciating pains will start to appear. This is like stage 5 of alcohol addiction; it is your body crying for more heroin.

Since the teenage brain is more easily addicted, you can already imagine the damage that heroin does to a younger person's brain. A good way to put it is to imagine having a 10-hour long orgasm. How are you supposed to be able to enjoy anything else? Nothing else provides the same amount of pleasure. While thinking about it, I came to the conclusion that heroin is simply too good for our brains. The human brain cannot handle it.

Conclusion

In conclusion, we have explored the intricate workings of the brain and the impact that drugs can have on its development and function, especially during adolescence. We have seen that drugs can disrupt the delicate balance of neurotransmitters and affect various brain regions, leading to lasting neurological changes and increased risk of addiction and mental health issues.

As mentioned in the introduction, one of the key motivations behind this research is to promote knowledge and awareness about the dangers of drug use. I believe that education is a critical first step in helping teenagers and other individuals make informed decisions and avoid potentially harmful situations.

While this research has provided valuable insights, I acknowledge that there are limitations to our understanding of the brain and drug use. Unfortunately, I was only able to scratch the surface of this vast and complex field, and there is much more to explore and discover. Nonetheless, I hope that this research can serve as a starting point for further investigation and maybe even as a call to action for policymakers, educators, and communities to prioritize drug education and prevention efforts.

Personally, writing this research has been a transformative experience, as I have gained a deeper appreciation for the intricate workings of the brain and the devastating effects of drug use. I am grateful for the opportunity to learn and grow through this process, and I am excited to use this knowledge to make a positive impact in the future. I believe that with increased awareness, education, and support, we can reduce the prevalence of drug use and promote healthy and fulfilling lives for all individuals.

I hereby conclude this research with the following words: if you still want to consume, it is at the cost of your most valuable organ. Your brain.

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