

**Council on Chemical Abuse  
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**The Science of Addiction:  
Rewiring the Brain**

**David Reyher, MSW, CAADC  
Behavioral Health Program Director  
Alvernia University**



**"THOSE WHO CANNOT  
CHANGE THEIR MINDS  
CANNOT CHANGE ANYTHING.**

**GEORGE BERNARD SHAW**



# Defining Addiction

## National Institute of Drug Abuse:

“A chronic, relapsing **brain disease** that is characterized by compulsive drug seeking and use, despite harmful consequences.”

## American Society of Addiction Medicine:

“A primary, chronic **disease** of **brain** reward, motivation, memory and *related circuitry*.

Dysfunction in these *circuits* is reflected in...  
pathologically pursuing reward and/or relief by  
substance use and other behaviors.”

# Is Addiction a Brain Disease?



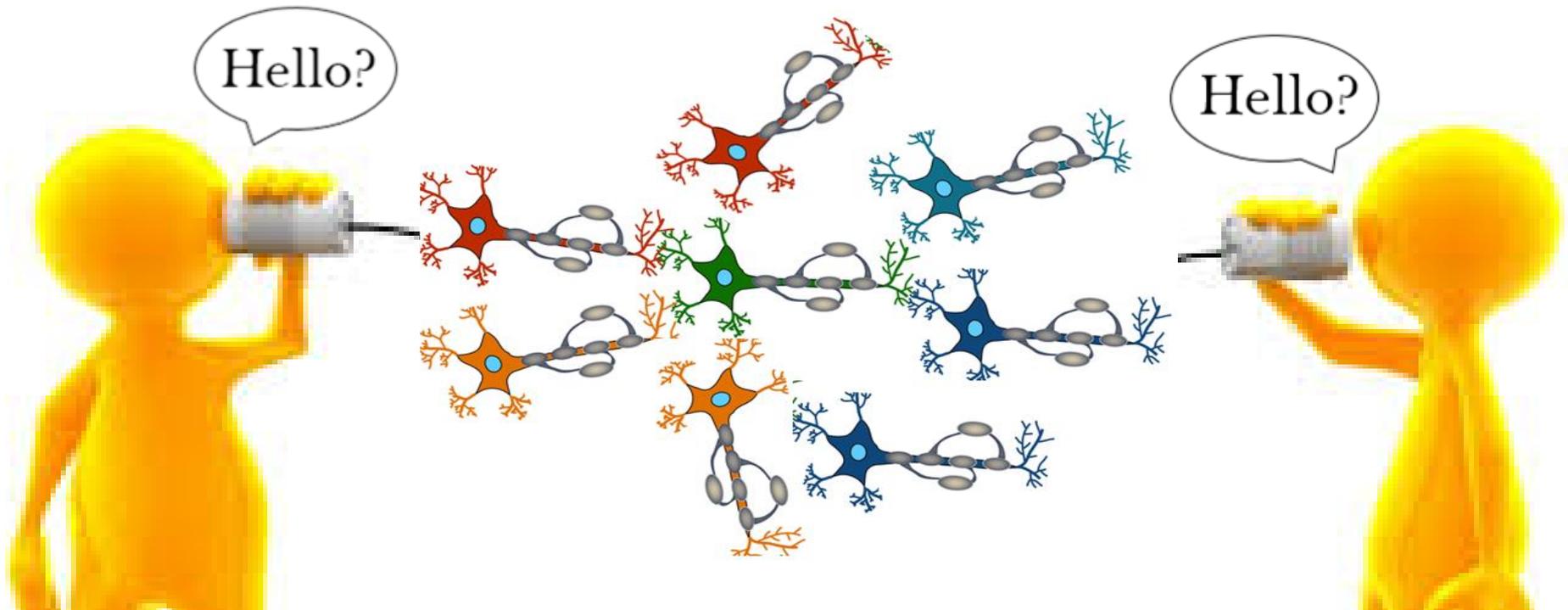
A **disease** is a condition that negatively impacts or changes the way an organ or an organism functions, and is manifested by distinguishing signs and symptoms.

- ☑ Addiction negatively impacts and changes the brain by *rewiring* its structure and functions.
- ☑ Addiction is manifested by distinguishing signs and symptoms.

This is why we can say that addiction is a **brain disease**.

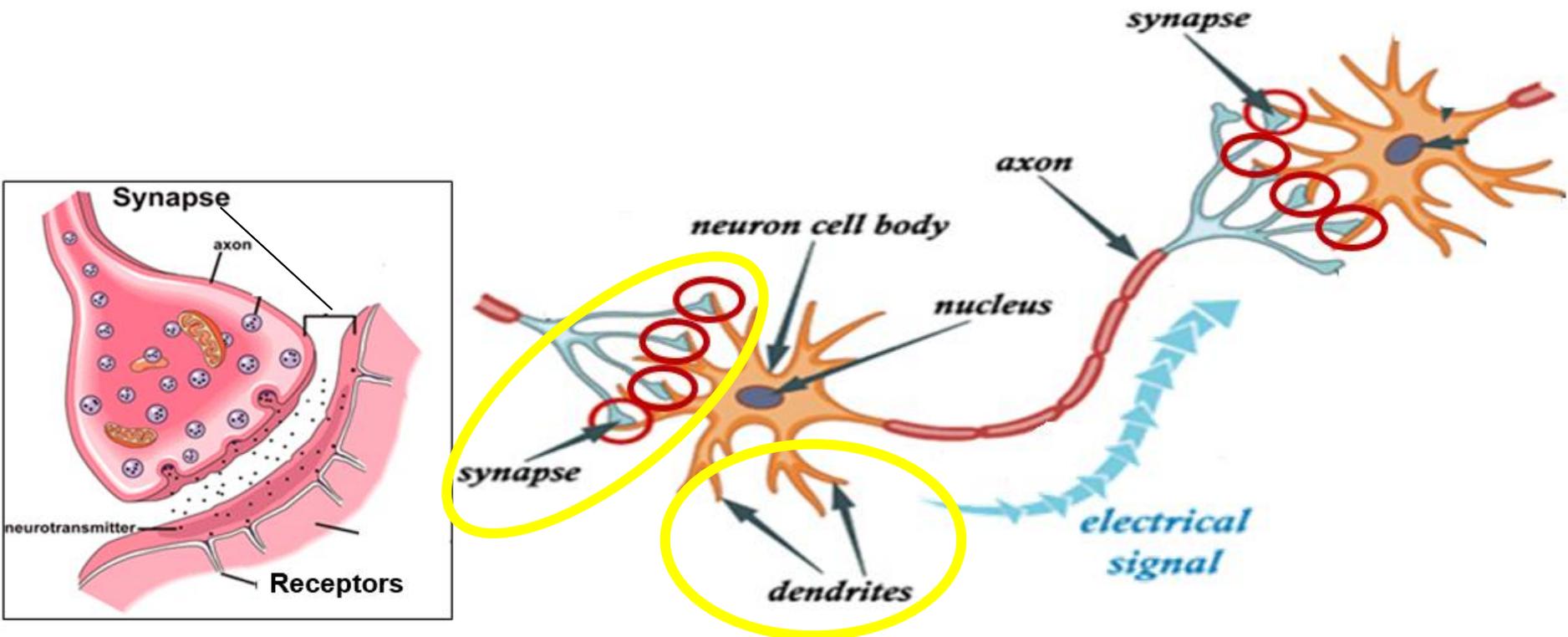
# How the Brain Works

The brain is made up of approximately **100 billion neurons** (*nerve cells*) which are in constant communication with each other.



# Neurotransmission

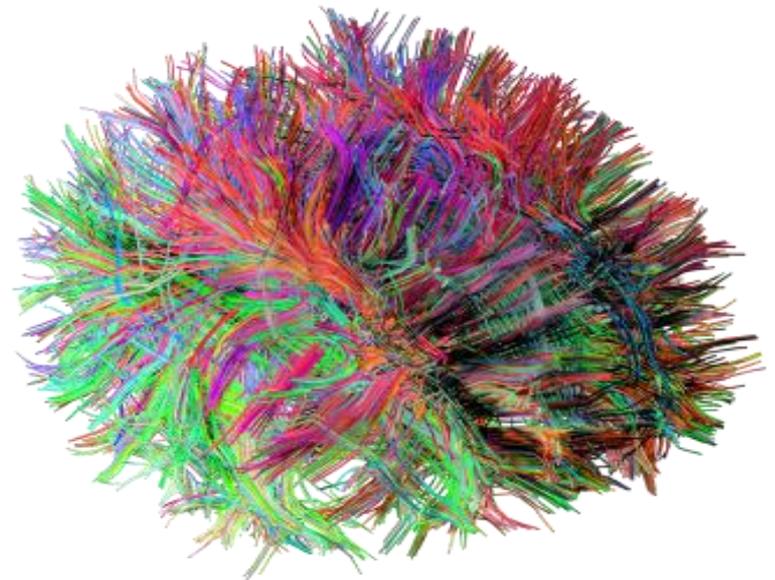
**Neurons** communicate by sending different chemical **neurotransmitters** (*dopamine, serotonin...*) through the synapses between **neurons**.



# Neural Pathways

**Neural pathways** are interconnected neurons that work together to communicate among different areas of the brain and nervous system.

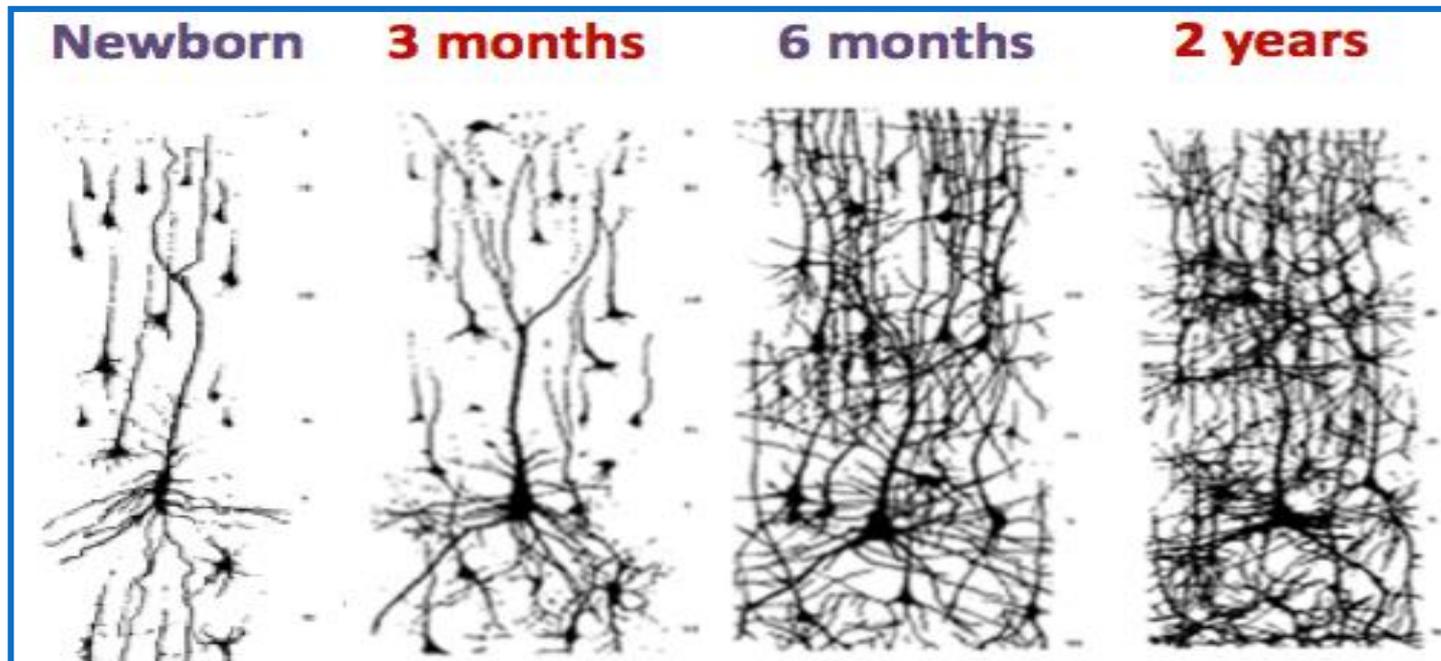
**Neural pathways** perform all of the brain's processing functions and make up its *wiring system*.



# Synapse Formation



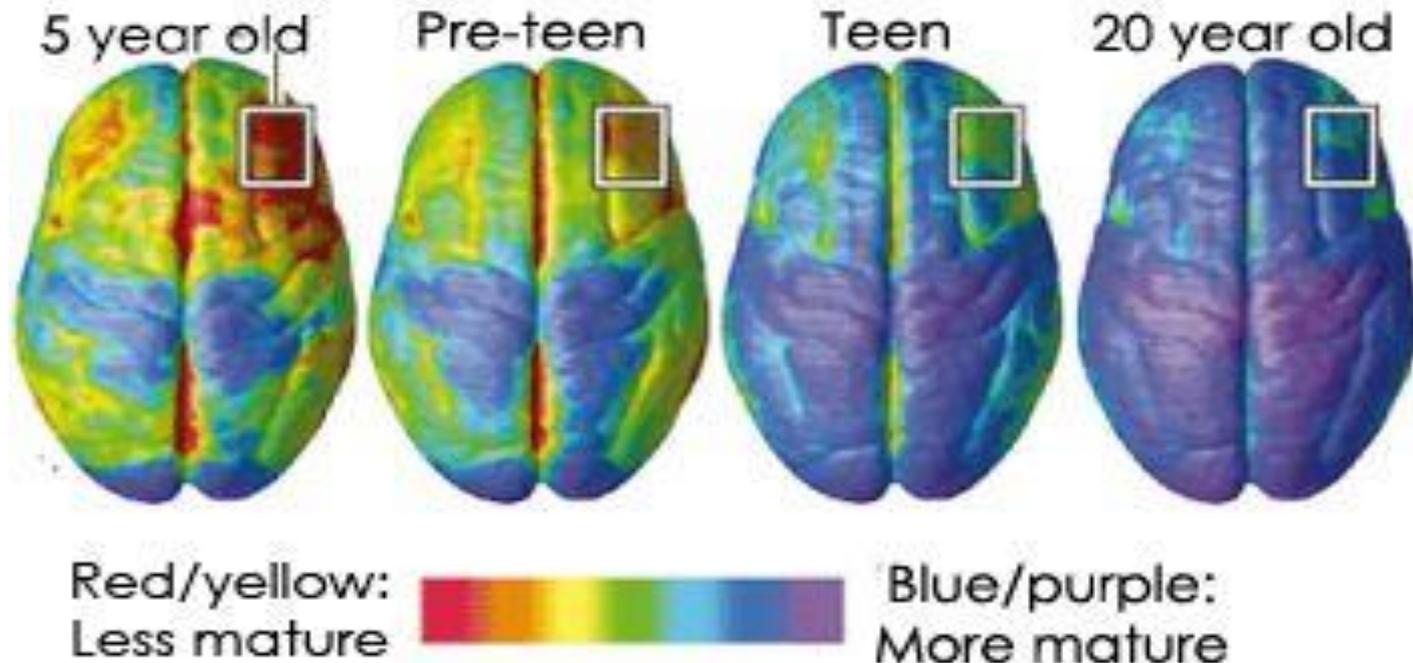
Neural pathways grow and develop through a *biological* process of “**synaptogenesis**” as connections form between neurons.



# Neural Development



During our first 20-25 years **neural pathways** consolidate and strengthen, expanding our *physical, mental* and *emotional* abilities.

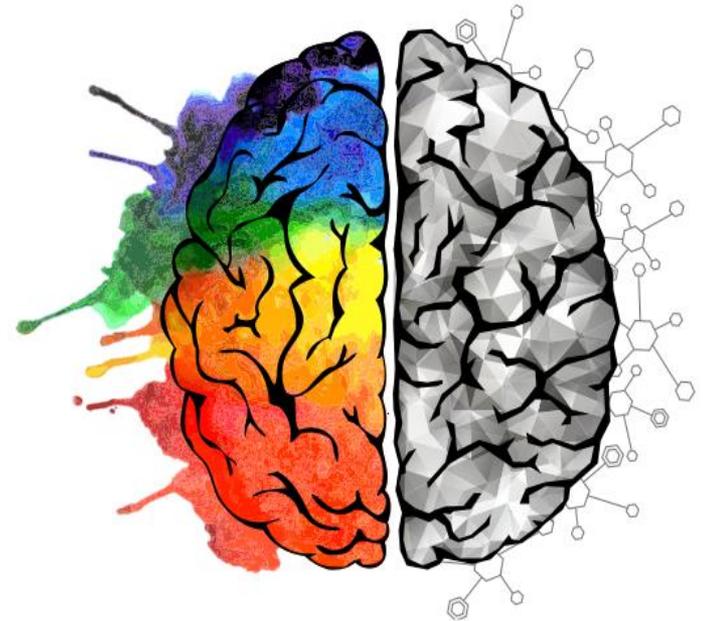


# Brain Plasticity

Science used to believe the brain was “*hard wired*” and that the *wiring* remained fixed for life.

We now know this is not true.

In many ways the brain has “**plasticity**”, which refers to *its ability to change, modify its structure, functions, connections, and to “re-wire” itself.*



# Neural Pathway Development

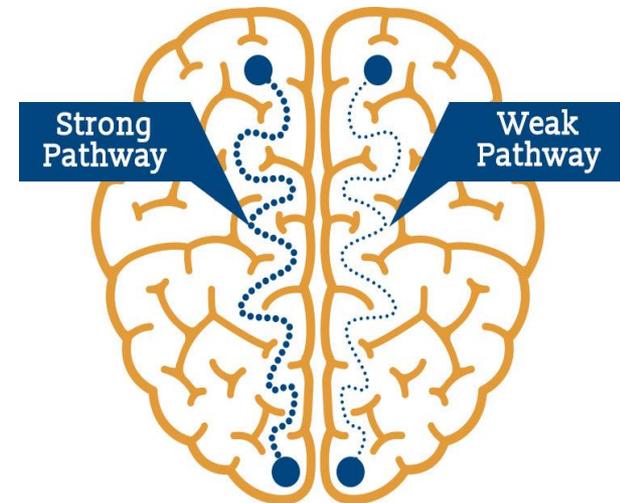
When neurons communicate *repeatedly*, they “**wire together**” and the **neural pathway** between them strengthens. With repetition, *patterns* emerge which then become *habits* and these eventually become *automatic*.



Neurons that fire together...  
wire together...

# Neural Pathways and Addiction

The fact that **neural pathways** can *wire together* and be programmed to become habitual and automatic helps to explain **addiction**.



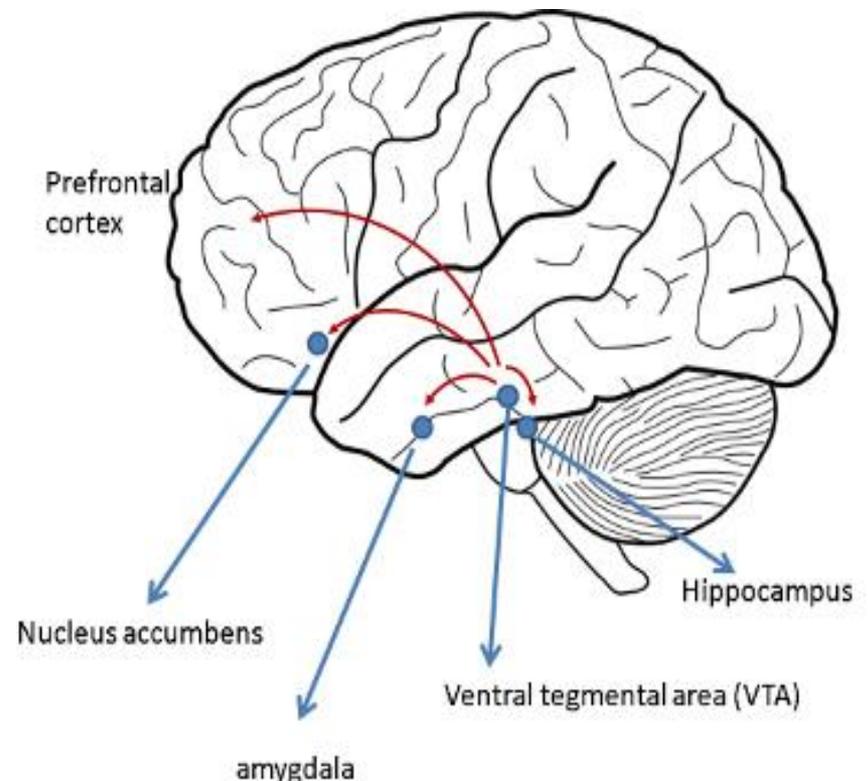
But **addictions** are more than mere “*habits*”, so to understand **addiction** as a **brain disease** we have to understand the functions of some specific and important parts of the brain.

# The Reward Pathway

The **Reward Pathway** is a **neural pathway** in the brain which regulates the experience of **“reward”**.

The **Reward Pathway’s** basic function is to ensure our survival!

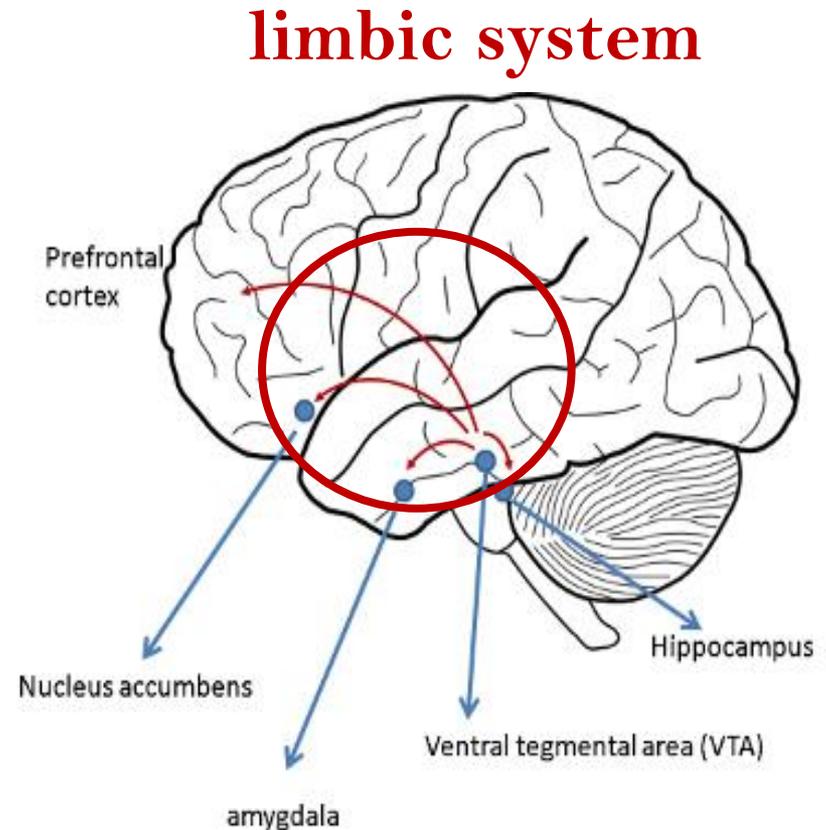
## Mesolimbic Dopamine (Reward) Pathway



# Major Components of the Reward Pathway



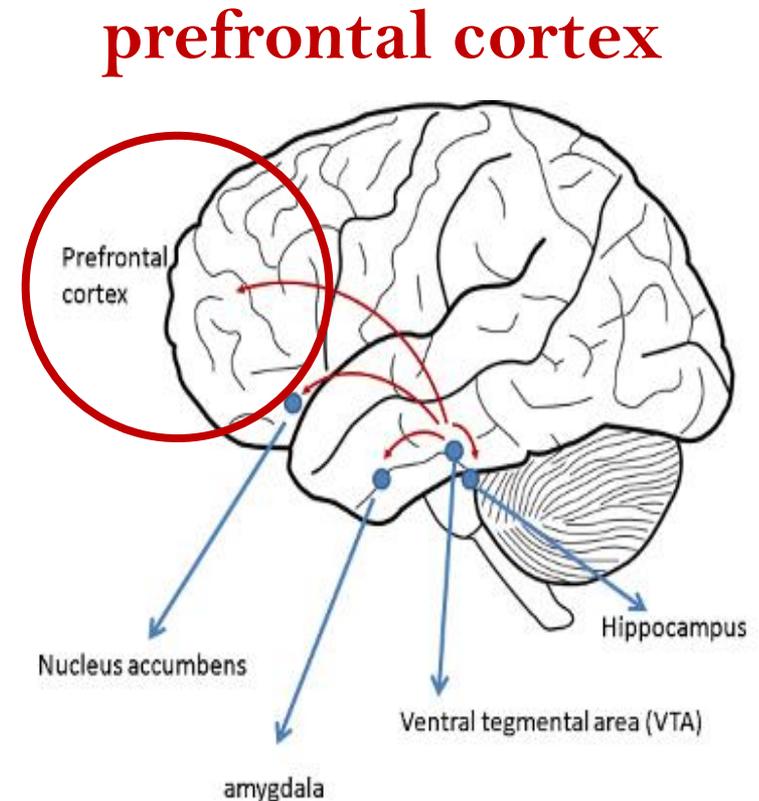
The **Reward Pathway** includes the **limbic system**, a subcortical region which plays an important role in meeting our *basic survival needs*.



The **limbic system** acts as the **GO** switch.

# Major Components of the Reward Pathway

The **Reward Pathway** also connects to the **prefrontal cortex**, which controls most *high level* cognitive functions such as judgment, problem solving, inhibition, impulse control, and regulation of emotions.



The **prefrontal cortex** acts as the **STOP** switch

# What is a “Reward”?



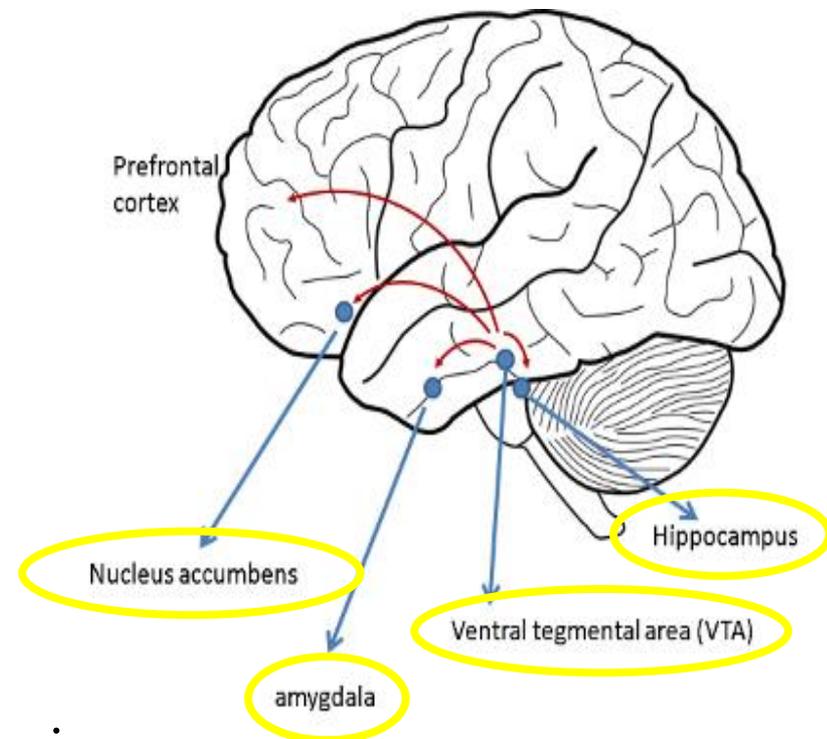
**Reward** refers to desirable and reinforcing qualities of a stimulus (*thing or event*), and includes:

- 1. Pleasure:** feelings ranging from satisfaction to euphoria received by a stimulus (“liking”).
- 2. Incentive Salience:** a desire (“wanting”) or craving (“needing”) for a reward.
- 3. Motivation:** the power and importance of an incentive and the actions taken to achieve a reward.
- 4. Learning:** associating a stimulus with a rewarding response through repetition and reinforcement.

# How the Reward Pathway Works

Various brain structures work together to create, remember and reinforce **rewards** from a stimulus:

- 1. Ventral Tegmental Area**  
releases *dopamine*
- 2. Nucleus Accumbens**  
processes *pleasure/reward*
- 3. Hippocampus**  
processes *memory*
- 4. Amygdala**  
processes *emotions and learning*



# The Role of Dopamine

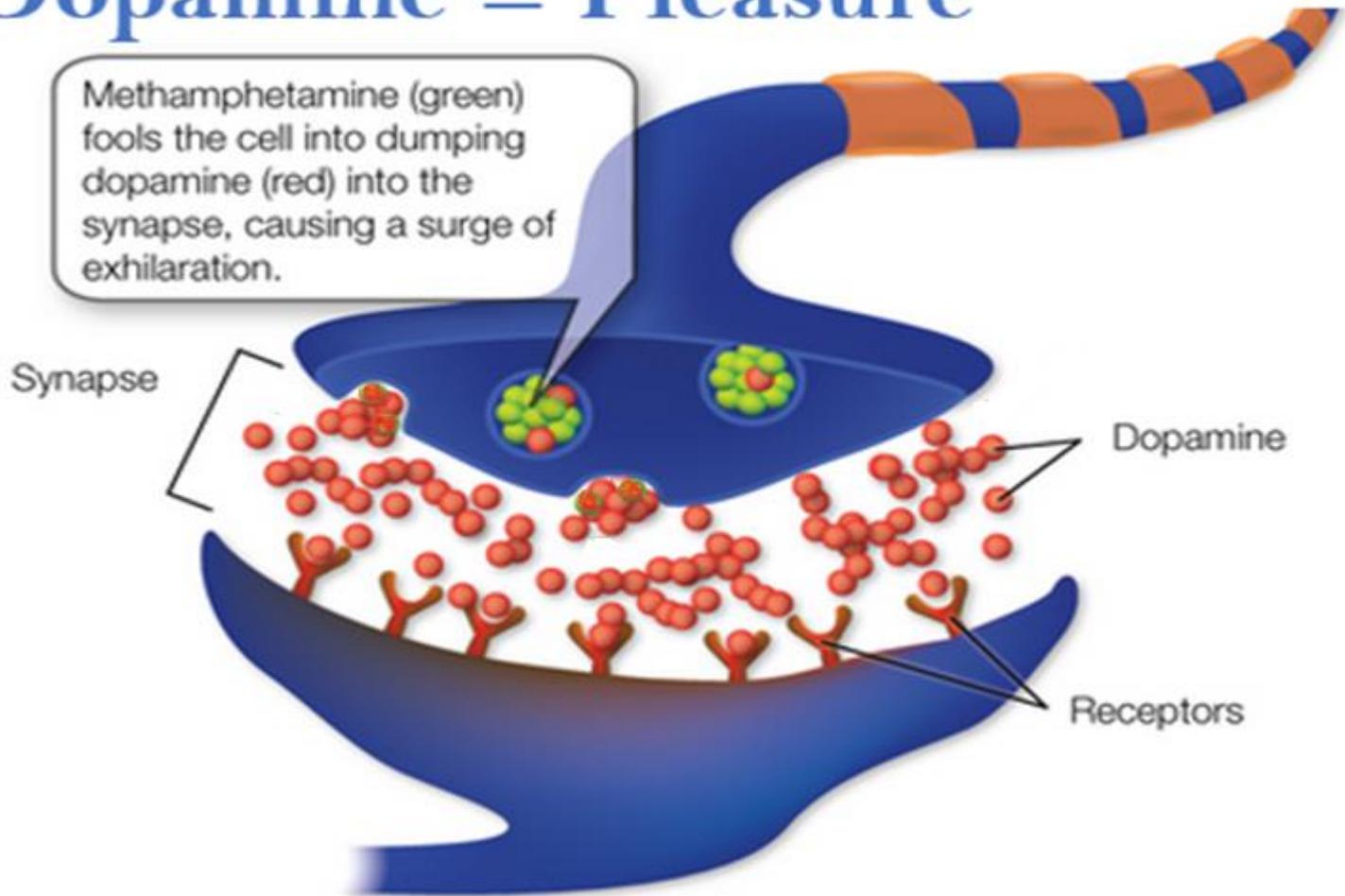
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We experience **rewards** from certain *substances* (food, drugs...) and *activities* (sex, gambling...) through the release of **dopamine**, which is primarily responsible for feelings of pleasure.

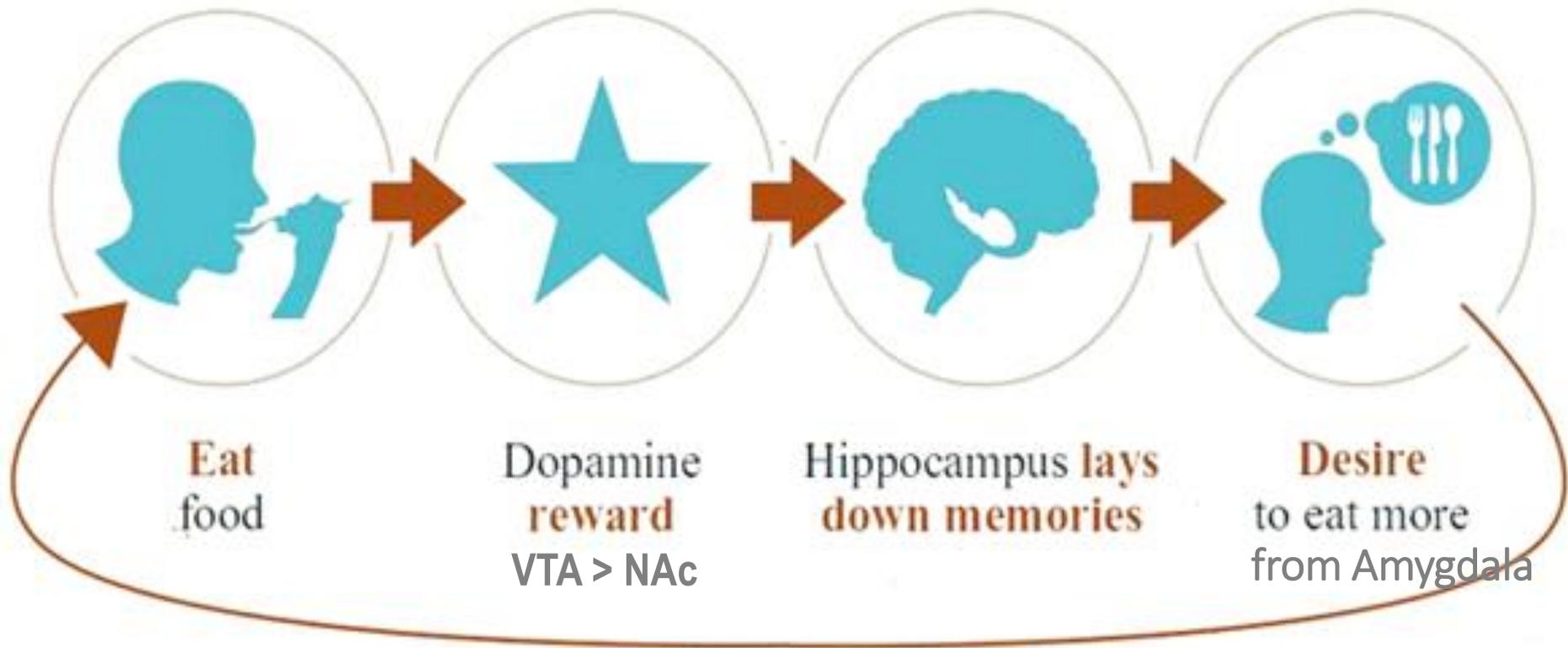
Not ALL substances and activities release **dopamine** into the Reward Pathway, which helps to explain why we become addicted to some things and not others.

# The Role of Dopamine

## Dopamine = Pleasure



# The Reward Pathway in Action



*“Hey, this cake is really good.  
I’m going to remember that for the future.”*

# The Reward Pathway in Action



# More Dopamine = More Pleasure

Certain substances and activities can increase brain **dopamine** levels by *significant* amounts:

- Foods high in sugar, fats and carbs: **50-100%**
- Activities like sex and gambling: **50-100%**
- Caffeine and nicotine: **100-200%**
- Alcohol and marijuana: **300-400%**
- Cocaine (powder and crack): **500-750%**
- Heroin (IV) and methamphetamine: **1,000%**

# Addiction: The Hijacked Brain

Through a combination of nature, nurture and repetitive use, pleasurable substances and activities can “**hijack**” the **Reward Pathway** and change the brain’s structure and function.

Once **hijacked**, the brain continues to seek pleasure and reward through an obsessive and compulsive *loop* despite negative consequences. This is what we call

**ADDICTION.**



# Hijacking the **Limbic System**: The Addiction Loop

1. Use of a substance or activity releases dopamine into the reward pathway creating pleasure (“*liking*”)
2. As use is repeated, learning and memories reinforce the rewards associated with the substance or activity.
3. For some people, structural and functions neurological changes begin to occur within the reward pathway.
4. Incentive salience develops (“*wanting*”, “*needing*”) and motivations for use change and strengthen.
5. Increasing intensity and frequency of cues and cravings trigger increasing amount/frequency of use.

# Hijacking the **Limbic System:** The Addiction Loop

With each repetition the **Addiction Loop** gets stronger, cravings begin to override reason and impulse control, and eventually use of the substance or activity becomes compulsive and automatic even as feelings of pleasure continue to *diminish* and negative consequences continue to *increase*.

# Hijacking the Prefrontal Cortex: The Loss of Control

The hijacked **limbic system** impairs functioning of the **prefrontal cortex** by progressively limiting and overriding important abilities:

- Critical thinking and reason
- Judgment and decision making
- Response inhibition and impulse control
- Salience attribution and motivation
- Emotional regulation and reactions
- ★ *Control (AKA Choice!)*

# The Addicted Brain

**Addiction** *rewires* the brain through structural and functional changes within the **Reward Pathway** that perpetuate addictive *thoughts, feelings and behaviors.*

The **Addicted** brain has been *reprogrammed* and *rewired* to continue the addiction automatically and uncontrollably.



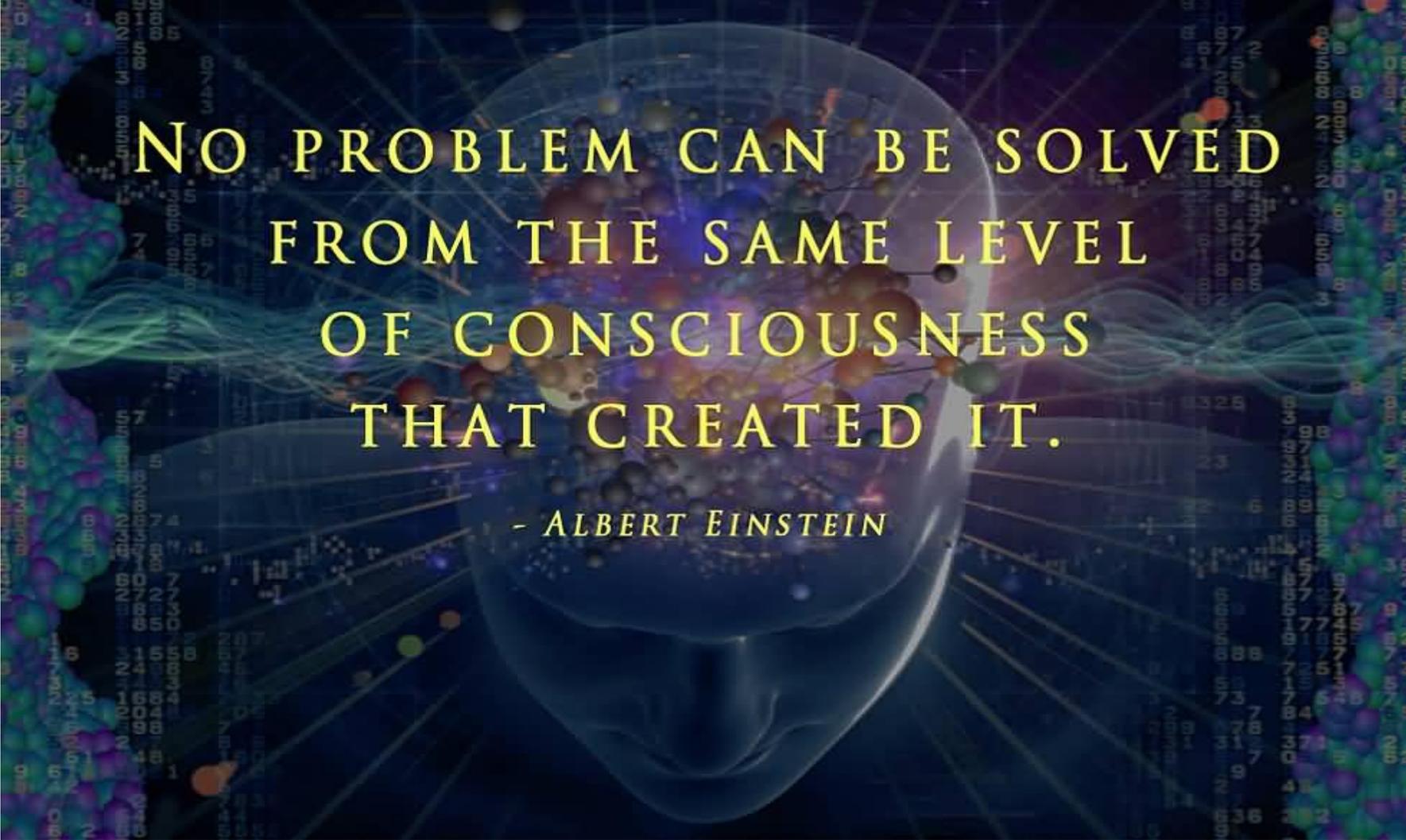
# Substance Use Disorders and the Hijacked Brain



## DSM-5 Criteria

1. Using larger amounts or over a longer period than intended
2. Unable to cut down or control substance use
3. Much time spent obtaining, using, or recovering from use
4. Craving or a strong desire or urge to use the substance
5. Use results in a failure to fulfill major role obligations
6. Continued use despite social or interpersonal problems
7. Important activities given up or reduced because of use
8. Recurrent use in situations where it is physically hazardous
9. Continued use despite physical or psychological problems
10. Tolerance – needing to increase use to get the same effect
11. Withdrawal symptoms or using to relieve/avoid withdrawal

# Recovery From Addiction



NO PROBLEM CAN BE SOLVED  
FROM THE SAME LEVEL  
OF CONSCIOUSNESS  
THAT CREATED IT.

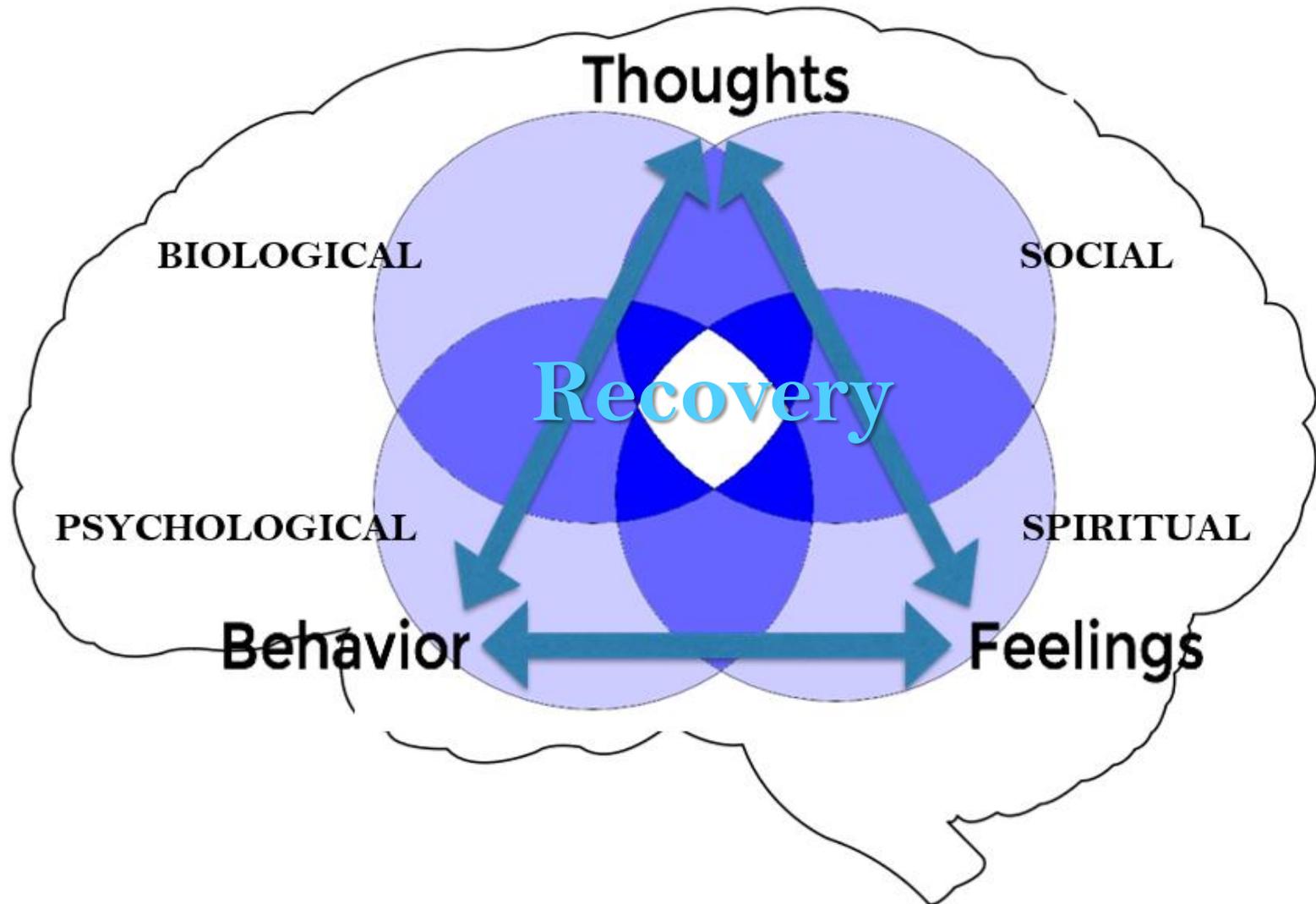
- ALBERT EINSTEIN

# Recovery From Addiction

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Recovery from addiction requires that **neural pathways** be *retrained* and *rewired*.

# Rewiring the Brain for Recovery: An Integrative Neuroscience Model



# Retraining the Brain for Recovery

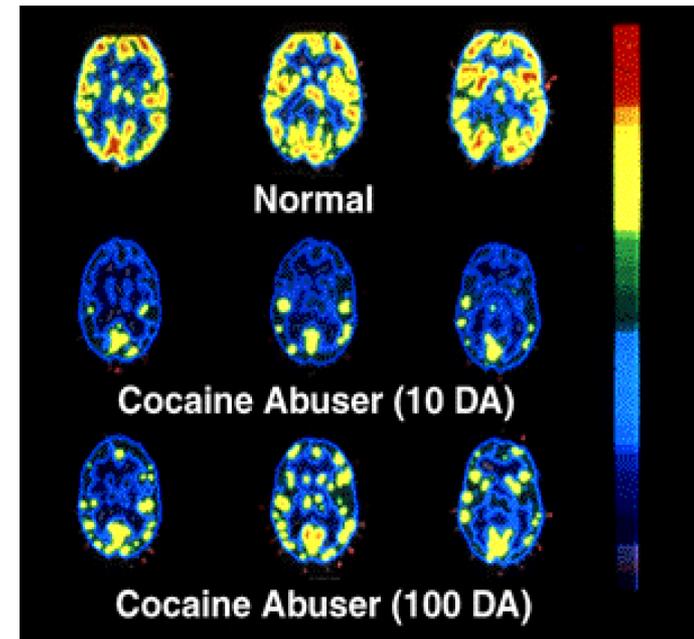
**Retraining the brain** primarily involves practicing *thoughts, feelings* and *behaviors* that:

1. **weaken** neural pathways in the **limbic system** that precipitate cravings, obsessive thoughts, emotional reactions and compulsive behaviors.
2. **strengthen** neural pathways with the **prefrontal cortex** that improve cognitive functioning, emotional regulation and impulse control.



# Rewiring takes Time

- The brain does not quickly or automatically return to “normal”.
- Making changes and new neural connections often takes *months* or *years*.
- Not *all* changes can be undone.
- The **reward pathway** remains susceptible to relapse.
- The brain is especially vulnerable to *cues* and *triggers* that can precipitate **craving**.



# Repetition

The key to neural pathway *rewiring* – and to recovery – is **repetition**. Without **repetition**, there is no **retention!**

Only through **repetition** of *thoughts, feelings* and *behaviors* can new patterns and habits emerge that will eventually be strong enough to overcome the old addictive patterns.

REPETITION  
REPETITION  
REPETITION  
IS THE MOTHER OF  
RETENTION

# Recovery is a Process, Not an Event

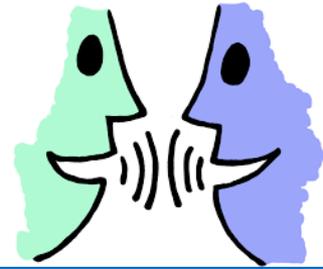
The requirements of **time** and **repetition** to *rewire* the brain are another way of saying:



Recovery is a  
**Process**  
not an event

Recovery from addiction requires **consistent** **repetitive** practice of new *thoughts, feelings* and *behaviors* over **time**.

# Talk Therapy and Neuroscience



Talking to a counselor or therapist can create changes in brain activity that serve to rewire and strengthen **neural pathways** within and between the **limbic system** and **prefrontal cortex**.

Therapy provides a very effective forum for people to examine their *thoughts, feelings* and *behaviors* and to learn and practice new ways of *thinking, feeling* and *acting*.

# 12 Step Recovery and Neuroscience



The ideas, principles and practices of “12-Step” recovery programs like Alcoholics Anonymous and others serve to ***rewire neural pathways*** within and between the **limbic system** and **prefrontal cortex**.

These programs are not simply “folk wisdom”, but rather have a sound basis in neuroscience as they function to ***retrain the brain*** in healthy new ways of *thinking, feeling* and *acting*.

# Rewiring the Brain: The Power of Cognition

- **Cognition** is the mental process of *thinking* which takes place in the **prefrontal cortex**.
- **Cognitive** abilities are significantly impaired in active addiction **and** during early recovery.
- *Rewiring* requires repetitive practice of various types of **cognitive** interventions.
- Structure, guidance and external supports are key – especially early in recovery.

# Rewiring the Brain: The Power of Emotion

- **Emotional** regulation refers to managing and tolerating *feelings*, which takes place in both the **limbic system** and **prefrontal cortex**.
- **Emotional** regulation is significantly impaired in active addiction **and** during early recovery.
- *Rewiring* requires repetitive practice of various types of **emotional** interventions.
- The goal is to reduce “survival” reactions by the **limbic system** and improve **emotional** control and responsiveness by the **prefrontal cortex**.

# Rewiring the Brain: The Power of Behavior

- **Behavior** stems largely from our thoughts and feelings, but is also a product of *learning* through association, reinforcement and observation.
- **Behaviors** are significantly impaired in active addiction **and** during early recovery.
- *Rewiring* requires repetitive practice of various types of **behavioral** interventions.
- We *learn* new **behaviors** best by association with others, observation of positive role models, and through positive reinforcement.

# Rewiring the Brain :

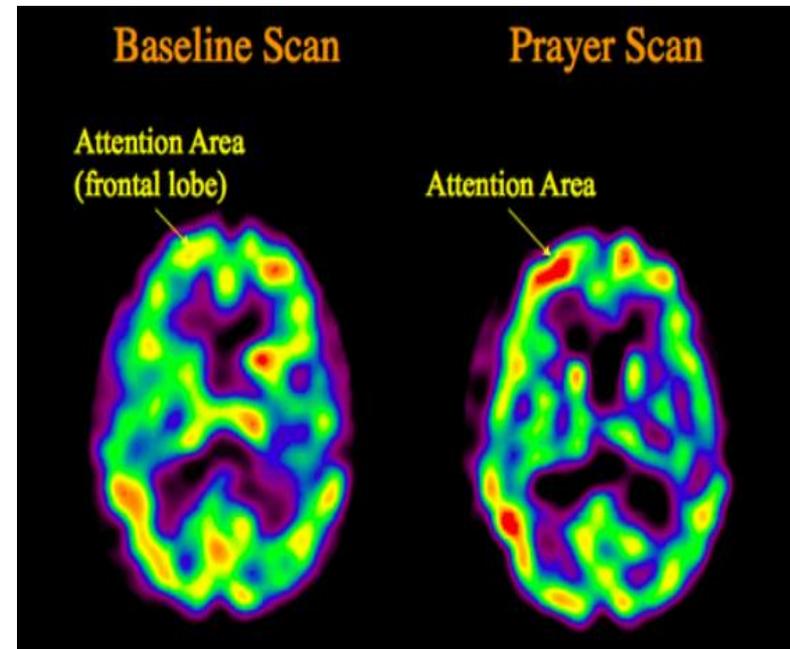
## The Power of Spirituality

1. **Spiritual** beliefs and practices strengthen pathways in the **prefrontal cortex** which help to regulate *thoughts, feelings* and *behaviors*.
2. **Spiritual** beliefs and practices weaken *craving*, pleasure-seeking motivations, and other “survival” reactions in the **limbic system**.
3. **Spiritual** beliefs and practices increase brain dopamine and serotonin levels which help to elevate mood and pleasure naturally without hijacking the **reward pathway**.

# Rewiring the Brain: Prayer, Meditation & “Mindfulness”

**Prayer** and **meditation** have been used throughout history to help focus attention on *thoughts, feelings* and *behaviors*, create awareness, and change consciousness.

**Mindfulness** is a mental state of focusing one's awareness on the present moment, while acknowledging and accepting one's thoughts, feelings and sensations without judgment.

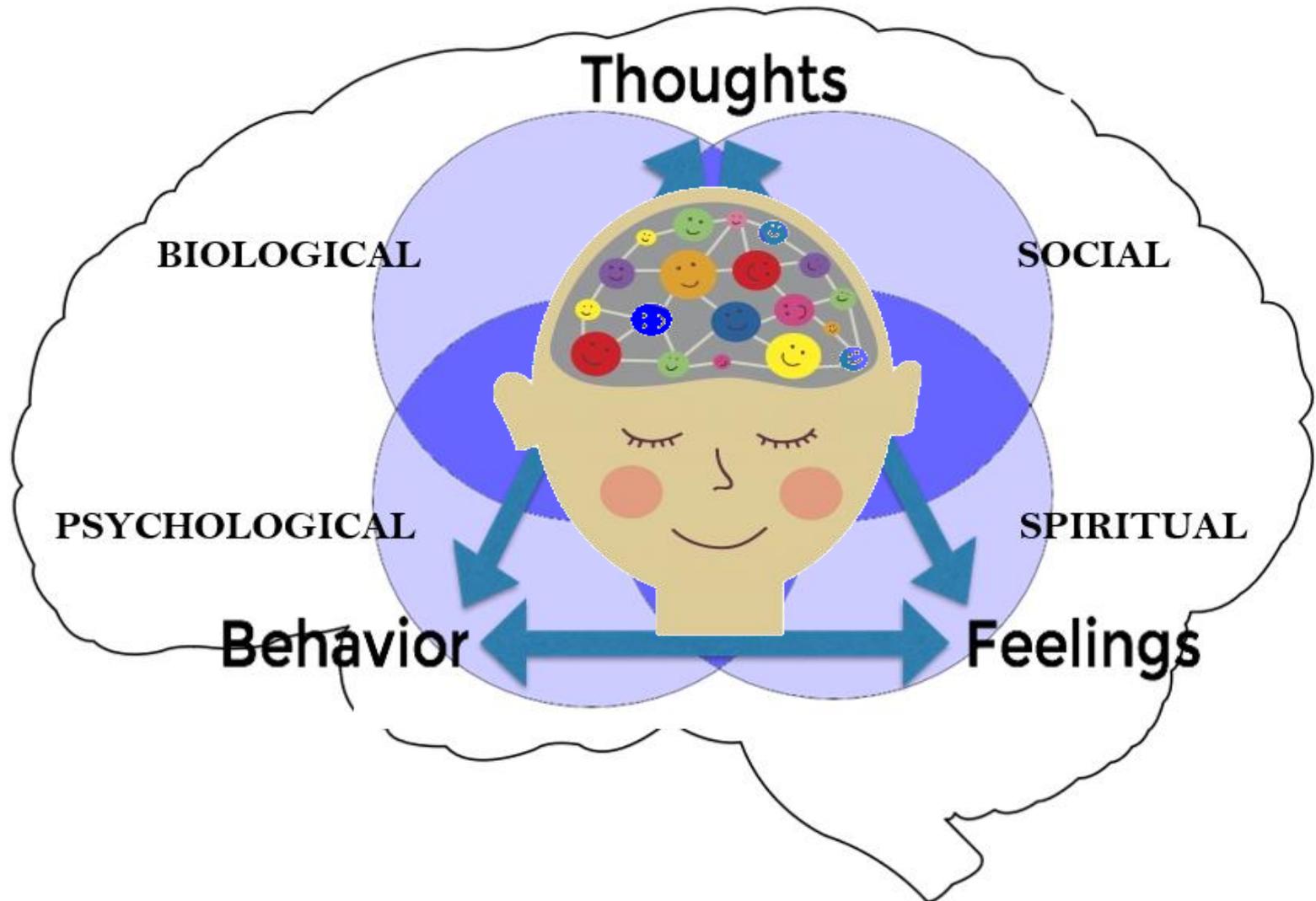


# Rewiring the Brain: The Power of Fellowship



- Having a strong and supportive **social network** and engaging in **fellowship** helps strengthen **neural pathways** that reinforce healthy *thoughts, feelings* and *behaviors*.
- The brain naturally seeks to emulate and imitate the most important people around us as a learned survival response.
- Retraining and rewiring the brain for recovery is more effective in the **social context** of **fellowship** with others rather than relying on our own individual *thoughts, feelings* and *behaviors*.

# Rewiring the Brain for Recovery



# Rewiring the Brain for Recovery

Watch your *thoughts*; they become *words*.

Watch your *words*; they become *actions*.

Watch your *actions*; they become *habits*.

Watch your *habits*; they become *character*.

Watch your *character*, it becomes your *destiny*.