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Dopamine's Role in Psychopathology and Biochemistry of Brain

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Dopamine (dihydroxyphenethylamine) is an organic compound from the family of Catecholamines and Phenylamines and plays an important role in the brain functioning. Dopamine is synthesized by precursors in the kidneys and brain. Dopamine is among the essential neurotransmitters in the brain, which is especially involved in pleasure and reward circuits, motivation, motor controls, functional ability, perception, sexual satisfaction, inhibition of milk secretion (lactation prevention), and nausea. This research aims to study the role of dopamine in psychopathology and biochemistry of the brain, through the document-analytical method. Review, evaluation and analysis of the previous articles imply that dopamine plays an important role in psychopathology and biochemistry of the brain. In conclusion, it is recommended for mentioned items to be empirically researched due to importance in basic and clinical research.

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1. INTRODUCTION

Dopamine (dihydroxyphenethylamine) is an organic compound from the family of Phenylamines and Catecholamines that plays an important role in the function of the body and brain [1-3]. Dopamine is synthesized by precursors in the kidneys, retina, and brain. In addition to the kidneys and brain of humans, dopamine has similar functions in several species of animals and plants. Dopamine acts as a neurotransmitter in the brain and a hormone in the blood [4-7]. Generally, dopamine is stored in the dopaminergic neurons' vesicles and adrenal glands. Dopamine is among the most essential neurotransmitters in the human brainand retina. It is particularly involved in reward and pleasure circuits, motivation, motor controls, functional ability, perception, light vision, sexual satisfaction, inhibition of milk secretion (lactation prevention), nausea, fear, anxiety, and other cognitive, learning, behavior and motor factors [8-11].

2. FIRST TOPIC: DOPAMINE

The molecular structure (chemical formula) of dopamine consists of a catechol structure (a benzene ring with two hydroxyl side groups) with one amine group attached via an ethyl chain (NH4-). Dopamine is the simplest molecule from the family of Catecholamines. Due to Dopamine's amino unit, it is known as an organic base and causes an acid-base reaction in acidic environments.

According to IUPAC (International Union of Pure and Applied Chemistry that names the chemical molecules), the name (ID) of dopamine is as follows:

IUPAC ID: 4-(2-aminoethyl) benzene-1,2-diol.

The general formula of the dopamine molecule is C8H12NO2. Its Molar mass is 153/18 g/mol, its density is 1.26 g/cm^3, its melting point is 128 °C, and no boiling temperature because it decomposes at high temperatures and its solubility in water is 100g per 60 mol.

Dopamine synthesis in different cells (in neurons and adrenal gland cells) consists of the following two primary and secondary pathways:

2.1 Primary Pathway

L-phenylalanine ---- L-Tyrosine ---- L-Dopa ---- Dopamine

2.2 And the Secondary Pathway Includes the Following

1. L-phenylalanine --- <L-Tyrosine --- <p-Tyramine ---- <Dopamine
2. L-phenylalanine ----- <m-Tyrosine ------ <m-Tyramine ------ <Dopamine

2.3 Second Topic: Dopaminergic Pathways in the Brain

Dopamine is among the most essential neurotransmitters in the human brain, which is particularly involved in pleasure and reward circuits, motivation, motor controls, functional ability, perception, sexual satisfaction, inhibition of milk secretion (lactation prevention), and nausea.

The dopaminergic pathways are among the most vital pathways in the brain. The nerve cells that move throughout the pathways are called dopamine neurons. Each pathway is a series of projection neurons, consisting of individual dopamine neurons. The dopamine neurons of the dopaminergic pathways synthesize and release the neurotransmitter at the related synapses. These neurons have axons that extend the entire length of their designated pathway, and theircell bodies produce enzymes that synthesize dopamine.

In the human brain, the cells that have the highest dopamine production are the dopaminergic cells of the Substansia Nigra (Latin for Black substance) or Pars Compacta, which is known as the black substance due to its secretion of melanin? (which is a black pigment) in these areas.

The functions associated with dopaminergic pathways in the human brain include executive, reward, learning, nerve control, motivation, and glands. Any disorder or damage in the function of dopaminergic pathways and related nuclei leads to diseases such as Parkinson's disease (PD), addiction, ADHD, and restless legs syndrome.

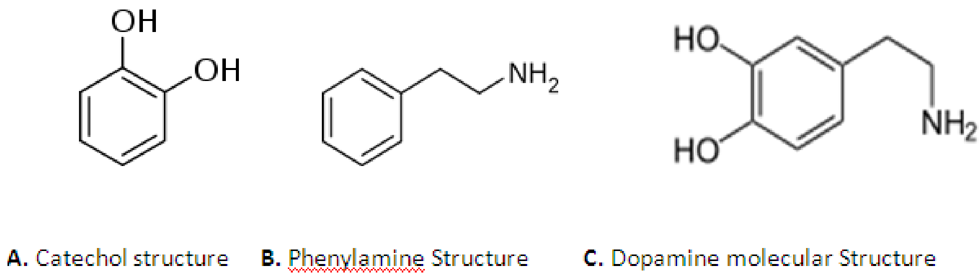


Fig. 1. Molecular structure of Catechol (A), Phenylamine (B), and Dopamine molecule (C)

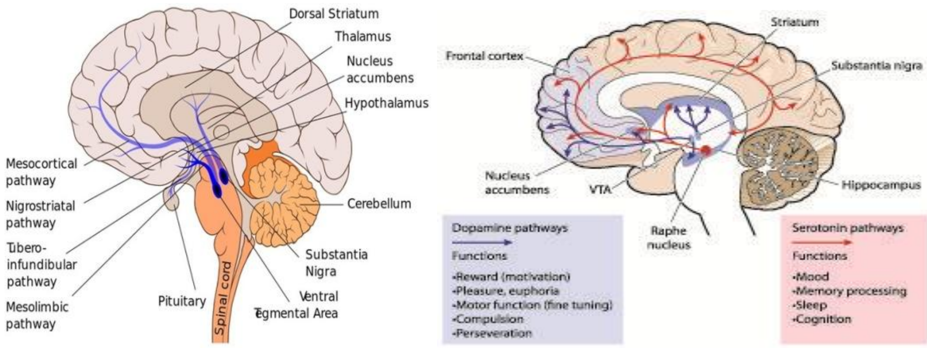


Fig. 2. Dopaminergic pathways in the human brai

"The Perikarya (somas) of neurons produce some kind of enzymes that synthesize dopamine. Then they are sent through their projected axons to their destined synapses, the place where most dopamine is produced. Nerve cells of dopaminergic pathways in these areas, such as the Pars Compacta (black substance), tend to be colored because of melanin which is a black pigment. Dopaminergic pathways play an important role in several functions such as executive, reward, learning, motivation and neuromuscular control."(1).

"Any disorder in these pathways and related nuclei may lead to diseases and disorders such as Parkinson's (2), Attention Deficit Hyperactivity Disorder (ADHD) (3), Obsessive-compulsive disorder and addiction (OCD) (4) and restless legs syndrome".(5)

There are many dopaminergic pathways in the brain; the six most essential and main pathways are as follows:

2.3.1 Mesolimbic pathway

The pathway that takes dopamine from the Ventral Tegmental Area (VTA), which is located in the midbrain, to the corpus striatum. This pathway includes nucleus accumbens and olfactory tubercle (OT), and associated disorders are ADHD, Schizophrenia, and addiction.

2.3.2 Mesocortical pathway

The word Mesocortical is derived from two words meso (refers to midbrain), and cortical (refers to the cortex). The mesocortical pathway plays a role in executive functions, and disorder in the secretion of dopamine in this pathway causes ADHD, addiction, and schizophrenia.

2.3.3 Nigrostriatal pathway

This pathway delivers dopamine from the Pars Compacta to the caudate nucleus and cerebral cortex. The black substance is located in the midbrain, the caudate nucleus, and the cortex in the dorsal striatum. Related disorders are Parkinson's disease, Tourette's syndrome, and addiction.

2.3.4 Tuberoinfundibular pathway

This pathway leads dopamine from the arcuate nucleus in the hypothalamus to the hypophysis (pituitary gland). The function of this pathway inhibits prolactin (PRL) secretion. Any disorder related to it leads to Hyperprolactinemia.

2.3.5 Incerto hypothalamic pathway

This pathway that comes from the zona incerta influences the hypothalamus and locomotor centers in the brainstem. The functions associated with this pathway include visceral and sensorimotor activities, and the disorders related to it are tremors in the limbs, particularly the head and hands.

2.3.6 Hypothalamo spinal projection tract

This pathway influences locomotor networks in the spinal cord and brainstem. The associated process regarding this pathway is the motor function process and the related disorder is Restless Legs Syndrome.

In addition to the above pathways, we mention other pathways, such as:

- VTA → Amygdala (mesoamygdaloid pathway)
- VTA → Hippocampus
- VTA → Cingulate cortex
- VTA → Olfactory bulb
- SNc → Subthalamic nucleus

2.4 Third Topic: The Role of Dopaminergic Tracts in Brain Functions

Dopaminergic pathways play different roles in various areas of the brain in terms of function (process). They cause processes such as reward and pleasure, forming the models of reinforcement learning (RL) (negative and positive) and associated disorders.

"The dopaminergic pathways that project from the substantia nigra pars compacta (SNc) and ventral tegmental area (VTA) into the striatum (i.e., the nigrostriatal and mesolimbic pathways, respectively) form one component of a sequence of pathways known as the cortico-basal ganglia-thalamic-cortical loop." (7)& (8)

The classification of the above-mentioned pathways is considered in researches and studies that are associated with many mental illnesses. Because:

"The nigrostriatal component of the loop consists of the SNc, giving rise to both inhibitory and excitatory pathways that run from the striatum into the globus pallidus (the internal and pale part of caudate nucleus of brain), before carrying on to the thalamus, or into the subthalamic nucleus before heading into the thalamus. The dopaminergic neurons in this circuit increase the magnitude of phasic firing in response to positive reward error that is when the reward exceeds the expected reward. These neurons do not decrease phasic firing during a negative reward prediction (less reward than expected), leading to hypothesis that serotonergic, rather than dopaminergic neurons encode reward loss. Dopamine phasic activity also increases during cues that signal negative events, however dopaminergic neuron stimulation still induces place preference, indicating its main role in evaluating a positive stimulus. From these findings, two hypotheses have developed, as to the role of the basal ganglia and Nigrostriatal dopamine circuits in action selection. The first model suggests a "critic" which encodes value, and an actor which encodes responses to stimuli based on perceived value. However, the second model proposes that the actions do not originate in the basal ganglia, and instead originate in the cortex and are selected by the basal ganglia. This model proposes that the direct pathway controls appropriate behavior and the indirect suppresses actions not suitable for the situation. This model proposes that tonic dopaminergic firing increases the activity of the direct pathway, causing a bias towards executing actions faster."(9)

2.5 Fourth Topic: Neuropsychology of Dopamine

In terms of neuropsychology, dopamine's role is prominent and has been confirmed and reported by many experimental researchers. Dopamine's role in psychopathology and biochemistry of the brain is more prominent in some cases including Parkinson's disease, social anxiety, and schizophrenia.

In addition to senses of euphoria, pleasure, and reward, dopamine in the brain leads to the control of the locomotor system, particularly through the basal ganglia (in controlling small and delicate movements). As, particularly with aging and the gradual decreasing of dopaminergic neurons and dopamine secretion, the symptoms of Parkinson's disease, including tremors in the limbs, especially the trembling of the head and hands appear.

Another role of dopamine in the human brain is milk production following pregnancy and childbirth. This mechanism functions by stimulating dopamine receptors, which decreases the secretion of prolactin that leads to reducing milk production.

In addition to playing the role of a neurotransmitter in the brain, dopamine also plays the role of a hormone in the body.

2.6 Fifth Topic: Dopamine and the Brain Reward System

The reward and pleasure system is part of the brain's structures that is activated by interacting with reinforcing stimulus or pleasure stimulus. The brain reward and pleasure system is an essential messaging mechanism of the brain that notifies the body that its needs are being met. These needs can be food, water, sex, parental care, etc., which are all necessary for the survival of the human species. In general, the brain is a reward-needing system, and with every pleasant reward that is given to the brain, it becomes more inclined to that pleasure. According to this, the idea of addiction comes from the inclination of the brain to pleasure.

"When people are exposed to pleasure stimuli, the brain begins to increase the secretion of the dopamine neurotransmitter, and the function of areas in the brain that are related to dopamine will increase. The mesolimbic pathway is the most important brain region that is related to the pleasure and reward system. This pathway connects the Ventral Tegmental Area to the Nucleus Accumbens. The brain reward system is responsible for stimulation (for instance, needing, desire, and need for reward), COLLABORATIVE learning (primarily positive reinforcement and classical conditioning), and positive feeling, particularly for situations that recognize pleasure as a key component (For instance, happiness, joy, and euphoria."(14) & (15).

In terms of neuroanatomy, the brain structures that compose the reward system are located primarily within the cortico-basal ganglia-thalamo-cortical loop. In this loop, the basal ganglia portion (also known as basal nuclei) are five subcortical nuclei that play an essential role in motor control. These nuclei include the Putamen, the caudate nucleus; Black substance (Subtantia Nigra), subthalamic, and Globus pallidus (dorsal Pallidum). The nucleus accumbens and Caudate nucleus together are called the striate nucleus (corpus striatum). The primary role of the basal ganglia is to control movement and regulate body posture.

Table 1. Various roles of dopamine in the body

Role of dopamine in the body	
Vascular (Venous) stenosis	Dopamine causes vascular stenosis by inhibiting the release of norepinephrine (NE).
Excreting sodium and increasing the amount of urine	Dopamine causes excretion of sodium and increases the amount of urine.
Decreases insulin secretion	Dopamine decreases insulin secretion from pancreas.
Decreases gastrointestinal (GI) motility	Dopamine decreases the gastrointestinal motility.
Stops prolactin secretion	Dopamine in the pituitary gland causes prolactin secretion to stop that eventually stops the milk production.
Dopamine Antagonists Drugs: (1)	Like Metoclopramide, they reduce nausea, which is functioned by the D2 receptor antagonist.
Dopamine antagonists: (2)	Like Haloperidol and Fluphenazine, which are used as dopamine antagonists in the treatment of schizophrenia.

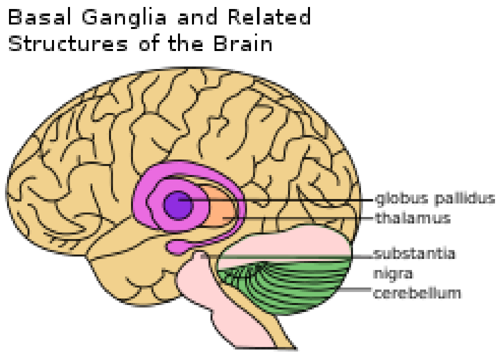


Fig. 3. Basal ganglia, Globus pallidus, and substantia nigra in the human brain

In the brain reward system, dopaminergic projection fibers play an important role. (The projection fibers consist of efferent and afferent fibers uniting the cortex with the lower parts of the brain and with the spinal cord.)

"Most dopaminergic pathways (for instance, neurons that use dopamine to make a connection with other neurons) are part of the brain reward system." (8) As:

"In these dopaminergic pathways, dopamine acts like D1-Like receptors or D2-Like receptors to stimulate (D1-Like) or inhibit (D2-Like) the production of cyclic adenosine monophosphate" (16).

Pleasure is considered to be a part of the reward. In this regard, the brain reward system also has a pleasure center. When something pleasant happens to us, the reward center will activate, and it feels like we want to do that fun thing again. This type of behavior includes all the pleasure behaviors such as laughing, eating, having sex, and even drug abuse.

2.7 Some of the Parts of the Brain that are Affected During this Process are

- Nucleus Amygdala: regulates emotions,
- Nucleus Accumbens: regulates dopamine production,
- Ventral Tegmental Area (VTA): produces dopamine;
- Cerebellum: is involved in controlling muscle function,
- Pituitary gland: produces several hormones in the pleasure circuit, such as :
- By secreting the beta-endorphin hormone reduces pain by blocking pain receptors;
- By secreting the oxytocin hormone increases self-confidence and calm;
- By secreting the vasopressin hormone increases the sense of dependence on the opposite pleasure.

2.8 Sixth Topic: Dopamine's Role in the Psychological Components of Wanting (Motivation) and Liking (Pleasure)

Wanting (motivation) and liking (pleasure) include psychologically separable components. As:

"Our reward system is an independent process of wanting and interest. The wanting component is thought to be controlled by dopaminergic pathways, whereas the liking component is thought to be controlled by opiate-benzodiazepine systems." (17)

Several studies show that motivational stimulus and motivation are directly associated with dopaminergic pathways and dopamine. In this regard, anhedonia is the inability to apprehend pleasure and is also referred to as a decrease in motivation. However, Anhedonia is also defined as the inability to feel pleasure. As:

"Researchers use it to refer to a decrease in motivation and motivational pleasure (wanting), a decrease and loss in sexual desire and pleasure, as well as a decrease in the ability to learn effectively. Neuroimaging studies across diagnoses associated with anhedonia have reported reduced activity in the OFC and ventral striatum."(18)

Neuroscientists including MIT researchers, Jasanoff Lab, who published their results in the journal, noted: "Dopamine plays several roles in the human brain. The most important roles are motivation, motor control, and behavior stabilization. Neuroscientists found that in addition to the motor cortex area, the area that is mostly affected by dopamine is the insular cortex. This area is essential for many cognitive functions associated with the perception of internal conditions of the body, including physical and emotional conditions. Like other neurotransmitters, dopamine helps neurons to make a connection with each other on short distances. Most of the brain's dopamine is released in the midbrain by neurons that are related with corpus striatum. In laboratory, Jasanoff and Lee injected dopamine into the corpus striatum and studied FMRI of the brain. They found that high concentrations of dopamine did not further activate neurons, instead, higher levels of dopamine cause neurons to stay active for longer periods. This finding indicates that there was a longer duration when dopamine was secreted and there was a longer response to reward. This may be have a relation to how dopamine reinforces learning, which is one of its main functions."(20)

2.9 Seventh Topic: Dopamine's Role in Fear and Anxiety

The mesolimbic pathway plays an important role in emotional behaviors. Fear is one of the emotional behaviors. "The fear response acts as a protective mechanism that causes a person to adapt, or adjust to the threatening factor. Fear has different degrees depending on the ability, type, duration of stimuli, and changes with each individual's characteristics."(21).

Fear and anxiety are among the disorders that cause problems with various intensities such as low level of productivity, lack of self-confidence, decreased practical and intellectual efficiency, feeling insecure, crawling into a corner of isolation, and similar cases.

"Various neurotransmitters, including serotonin, dopamine, gamma-Aminobutyric acid (GABA), cholecystokinin, and glutamate, are involved in developing the fear behavior. Also, by identifying and studying some neural pathways and centers of anxiety and fear and the impact of various neurotransmitters on this behavioral phenomenon, we can comprehend the important role of dopamine as the main neurotransmitter in this phenomenon "(22).

According to the results of many studies mentioned and presented in the previous lines, all approve that the mesolimbic pathway plays an essential role in the pleasure and reward system. As:

Dopamine D2 receptors are involved in adjusting emotional behaviors, including fear, etc. For example, in laboratory rats in "In vitro" and "In vivo", it has indicated that severe stress, such as shock, fear, social stresses, immobility, activates cortical/mesolimbic dopamine systems, and these effects are stopped with anti-anxiety and anti-fear drugs. 23).

In general, it has been shown that dopamine is a neurotransmitter in the central nervous system (CNS), particularly in the mesolimbic dopaminergic pathway, which plays an essential role in emotions. Dopamine has a dual potential for pathogenesis or drug treatment of central nervous system diseases, motor and behavioral disorders such as Parkinson's disease, ADHD, and schizophrenia.

3. DISCUSSION

Dopamine is an organic chemical from the family of Catecholamines and Phenylamines. It is an organic chemical of the natural monoamine alkaloid that acts as a stimulant in the central nervous system of the human body. Catecholamines are a component of the Fight-or-Flight hormones which are secreted from the adrenal glands {like norepinephrine (noradrenaline) and epinephrine (adrenaline)}. These hormones are part of the sympathetic nervous system and are released in response to biological stresses. In the human body, the common types of catecholamines are dopamine, adrenaline (epinephrine), and noradrenaline (norepinephrine), which are made from phenylalanine and tyrosine amino acids. Catecholamines are directly produced in the endocrine cells of the adrenal medulla (the inner part of an adrenal gland) as well as the postganglionic fibers of the sympathetic nervous system.

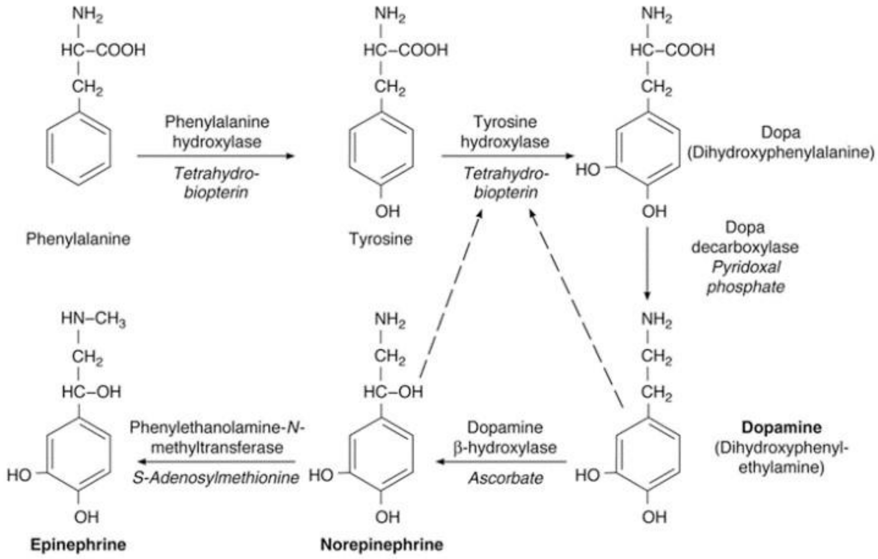


Fig. 4. Synthesis pathway of catecholamine

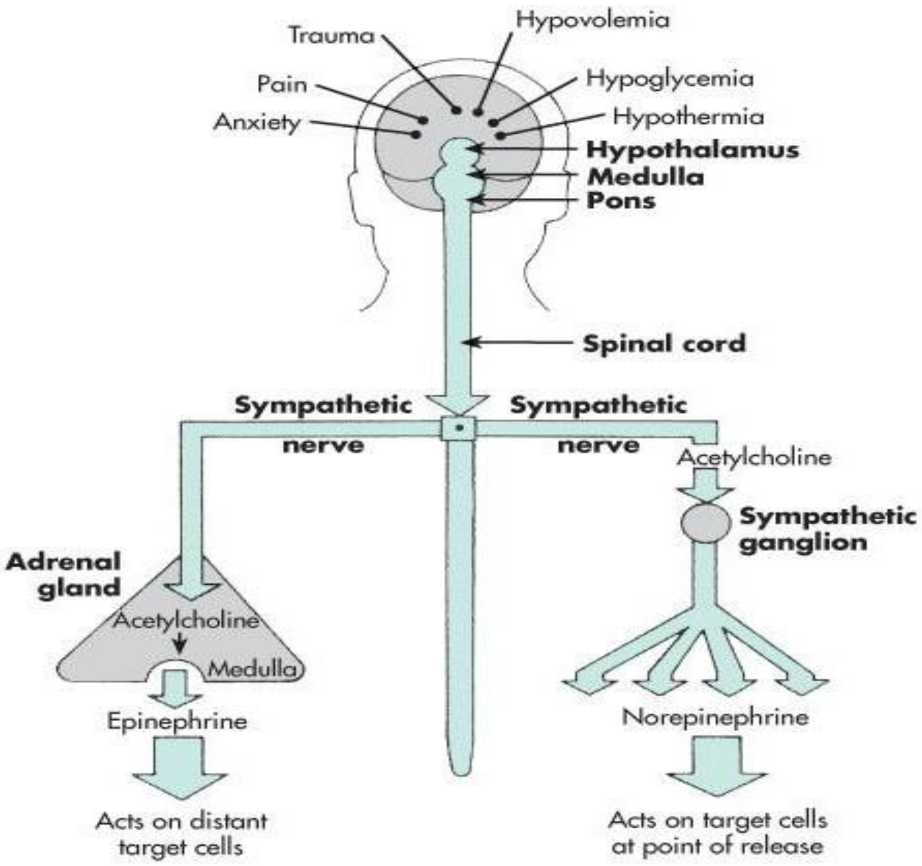


Fig. 5. Secretion pathway and function of Catecholamine in the body

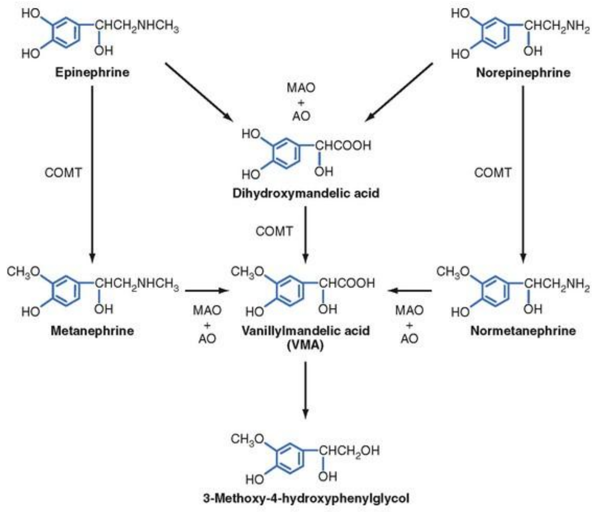


Fig. 6. Decomposition pathway of Catecholamine in the body

Dopamine plays the most essential role in creating reward and pleasure. By increasing dopamine in specific areas of the brain (that is called the reward system), a sense of euphoria (reward) will be created in an individual.

The process of decision-making is one of the individual adaptive behaviors. Several variables are involved in this process, which eventually results in the selection of one or several items concurrently.

"Nowadays, the topic of decision-making has become very important in human life. Given that human inclination is to make decisions is in the direction of achieving maximum profit, the topic of decision-making is more based on a cost-benefit approach. Assessing existing costs and conditions, such as trying and enduring delays and waiting to get the right profit will make sense in this regard. (25).

3.1 In the Decision-making Process, Various Parts of the Brain are Involved; these Parts Include

The nucleus accumbens, amygdala, and parts of the cortex, such as the anterior cingulate cortex (ACC) and the prefrontal cortex (PFC), have been confirmed in the process. Some neuropeptides, such as serotonin, glutamate, orexin, and, dopamine have an effect in this process, in which dopamine plays a key role." (26)

In addition to dopamine, orexin is one of the neuropeptides that is produced mostly in the lateral hypothalamus (LH) and includes two types of Orexin A: OxA and Orexin B: OxB. These neuropeptides act as modulators of nerve activity that are related to dopamine in the brain. In addition:

"The nucleus accumbens is a complicated structure of basal forebrain rostral that forms a great part of the ventral tegmental area. Nucleus accumbens have two parts, including the NAc Shell and the NAc Core. Each part has its own functional and neuroanatomical physiological networks. Studies have indicated that orexin receptors are highly released in both parts of the nucleus accumbens. But with due attention to anatomical studies, the NAc Shell area is more important for behaviors mediated by orexin because this area receives more orexin inputs." (27)

"The nucleus accumbens is a complex structure that plays an important part in the motivational behaviors of pleasure, reward, and emotions. It also plays a role in motor functions and regulating sleep. The nucleus accumbens is one of the areas involved in the "decision-making, cost-benefit" process and is part of the mesolimbic dopaminergic pathway. Dopamine neurons in the mesolimbic dopaminergic pathway play an important role in brain mechanisms, such as emotion, reward, motivation, and learning, and their activation happens through natural and artificial stimuli."(28).

"G proteins are the protein receptors that have one side inside the cell and the other side out the cell (switches across cell's membrane). This system is a messenger mechanism for certain chemicals such as neurotransmitters and hormones on the cell membrane's surface. This protein is consists of three subunits, alpha, beta, and gamma."(31)

Regarding the important role of dopamine in the human brain, dopaminergic pathways affect executive functions, reward, learning, neuromuscular control, and motivation. Dopaminergic pathways are a group of projection neurons in the brain's structure that are in control of the processes of releasing and synthesizing dopamine neurotransmitters. The neurons in this dopaminergic pathway are called dopamine. The axons of dopamine neurons are projected to synaptic targets where the highest amount of dopamine is produced.

"Any disorder in dopaminergic pathways and related nuclei can lead to many disorders and diseases, including Parkinson's disease, Obsessive-Compulsive Disorder (OCD), Attention Deficit Hyperactivity Disorder (ADHD), Addiction and Restless Legs Syndrome." (5)

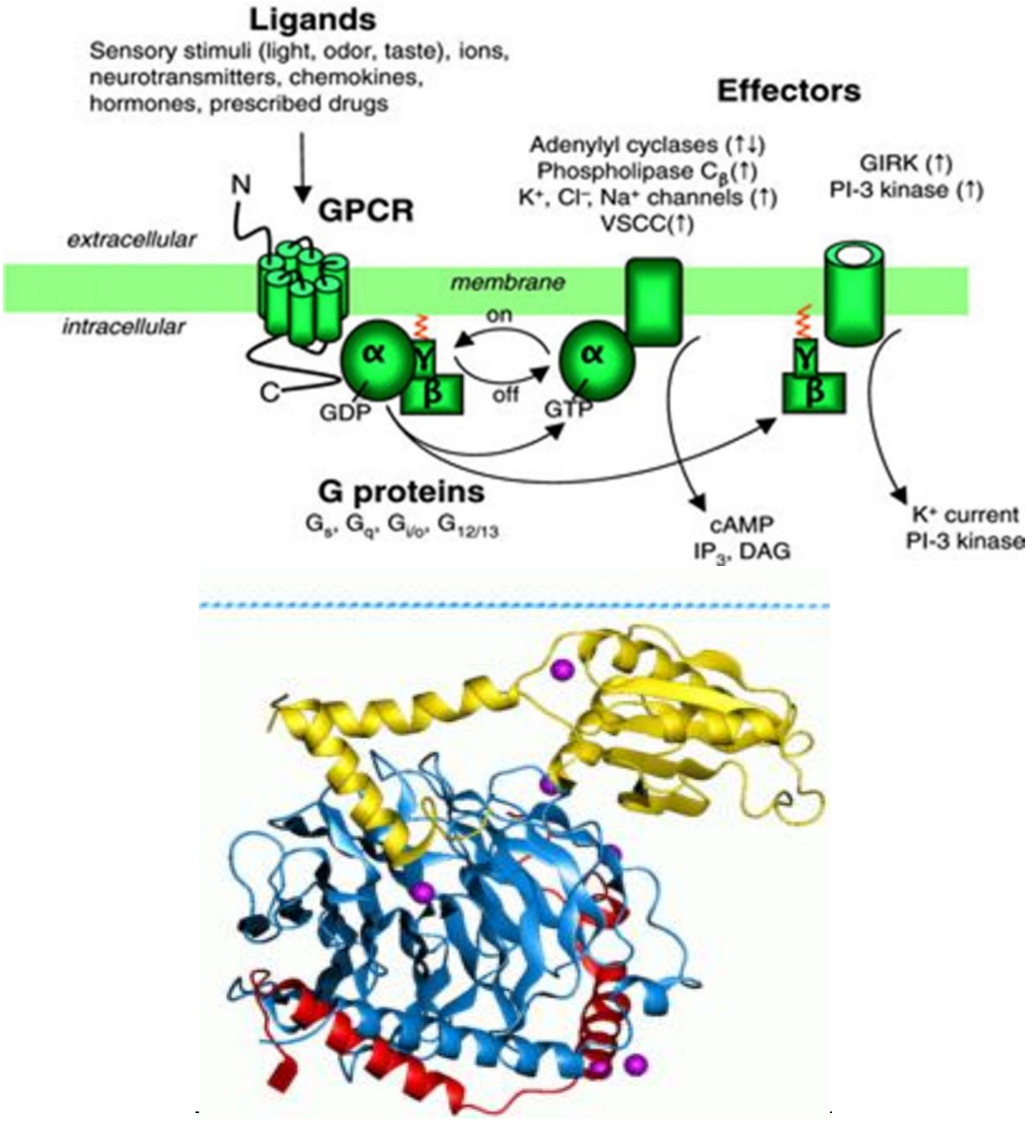


Fig. 7. G protein shape
*Alpha subunit (**yellow**) - Beta subunit (**blue**) - gamma subunits (**red**)*

4. CONCLUSION

The word "dopamine" comes from the combination of "dopa – meaning happiness and pleasure" and "amine – meaning amino acid". Therefore dopamine means a happy (pleasing) amine or a pleasing amino acid. The dopamine’s function in the brain of mammals, particularly humans, is to create energy, ability, and pleasure, and its lack or decrease leads to fatigue and boredom. Alongside dopamine, there is serotonin, which causes satisfaction and optimism and reduces stress. The biochemistry of men's brains often indicates a reduction in dopamine and a woman's brain indicates a reduction in serotonin. Due to this fact, men usually experience boredom and women usually experience depression.

Several receptors have been identified for dopamine, each with a particular role. Dopamine and other catecholamines decompose and become ineffective by monoamine oxidase enzyme (MAO) in neurons, and Catechol-O-methyltransferase (COMT) enzyme that is outside the neuron. After the dopamine’s decomposition, a substance called Homovanillic acid (HVA) appears, and together with measuring the cerebrospinal fluids (CSF), blood plasma, and urine, we can measure the activity of dopaminergic neurons in the brain.

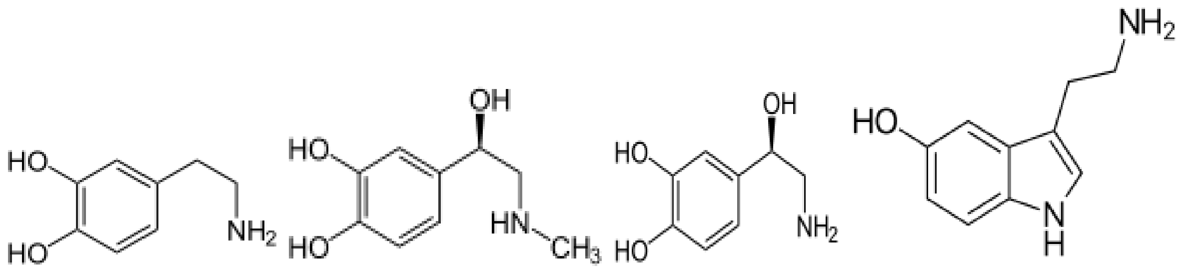
When the reward center of the brain is activated by dopamine neurotransmitters, a sense of pleasure and joy emerges in an individual. The neurons that form the pleasure and reward center of the brain communicate with each other through the dopamine’s biochemical language. When the dopamine neurotransmitter moves from one neuron to another through synapses, it evokes a feeling in a person from mild pleasure to intense euphoria. When eating delicious food, having sex, or generally during pleasant emotional experiences, dopamine is released, and consequently the concentration of dopamine in the brain reward system increases, and when dopamine’s concentration around the neurons increases, the reward center remains more active.

But what occurs after consuming addictive drugs and substances is that pleasure and joy eventually lead to unhappiness because by using an addictive drug, the number of dopamine receptors will reduce. Based on the law of balance, the brain calms and balances the over-activated pleasure center in this way. As dopamine receptors reduce in the reward center, less dopamine is trapped and accordingly, an individual feels the need to increase the dosage of addictive drugs and substances. This mechanism is the biochemical basis (tolerance). This means that drugs and substances with the previous dosage no longer have the initial effect and the addicted person must frequently increase the dosage to reach those initial pleasures.

Accordingly, following the gradual annihilation of dopamine receptors, the primary feeling of pleasure and joy is no longer achieved and it leads to worry, depression and, anxiety. The pain of quitting addiction is also a direct result of changes that addictive drugs and substances make in the dopamine system of the brain. Because quitting and avoiding addictive drugs and substances cause the brain to be deprived of the only source of dopamine, which has been the main cause of pleasure and happiness.

The brain has a natural and internal opiate that is called enkephalin. These natural opiates, reduce the sense of pain in painful areas of the body and activate the pleasure and reward center. By activation this reward center is not only for pleasure and joy, but also the main stimulus for repetition, motivation, and ultimately, learning and understanding. Accordingly, the need for pleasure resulting from eating food, pleasant odors, sexual activities, etc. in living beings, including humans, are all rational behaviors for their survival and the continuation of the generation.

The brain has various circuits and the reward and pleasure circuit is one of them. The complex interactions between the object (Objet) of empirical behaviors and biochemical interactions in these neuronal circuits transcend the subjects of mental (psychological) concepts. During these conceptualization processes in the course of empirical behaviors and biochemical interactions in neuronal circuits and associated synapses, it leads to facilitation in neurons’ synapses in the related brain circuits, and in this way, memories will be stored, and eventually, learning processes will take form.



A. Dopamine molecule **B.** Epinephrine molecule **C.** Norepinephrine molecule **D.** Serotonin molecule

Fig.8. Differences in chemical agents that lead to different emotions and perceptions in the brain.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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