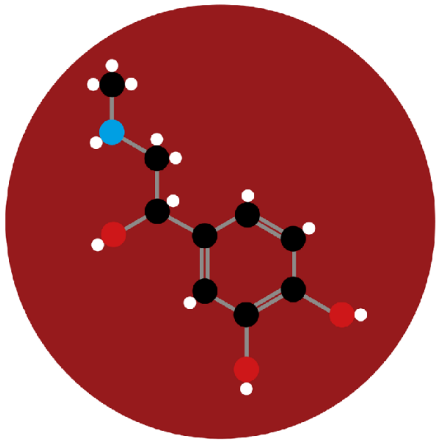
# CHEMICAL STRUCTURES OF NEUROTRANSMITTERS

## ADRENALINE $C_9H_{13}NO_3$

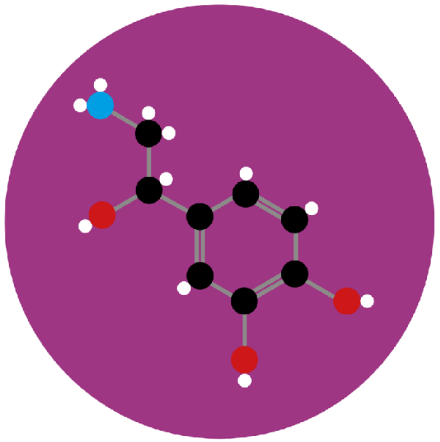
THE 'FIGHT OR FLIGHT' NEUROTRANSMITTER



Adrenaline, also known as epinephrine, is a hormone produced in high stress or exciting situations. It stimulates increased heart rate, contracts blood vessels, and dilates airways, to increase blood flow to the muscles & oxygen to the lungs. This leads to a physical boost, and heightened awareness. EpiPens, which are used to treat allergic reactions, work by injecting adrenaline.

## NORADRENALINE $C_8H_{11}NO_3$

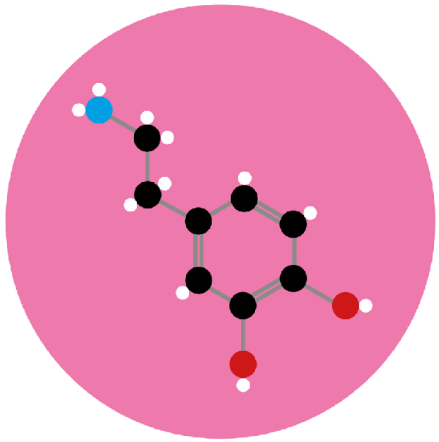
THE CONCENTRATION NEUROTRANSMITTER



Noradrenaline, also known as norepinephrine, is a neurotransmitter that affects attention & and responding actions in the brain. Alongside adrenaline, it is also involved in the 'fight or flight' response. Its effect in the body is to contract blood vessels to increase blood flow. Patients diagnosed with ADHD will often be prescribed drugs designed to help increase levels of noradrenaline in the brain.

## DOPAMINE $C_8H_{11}NO_2$

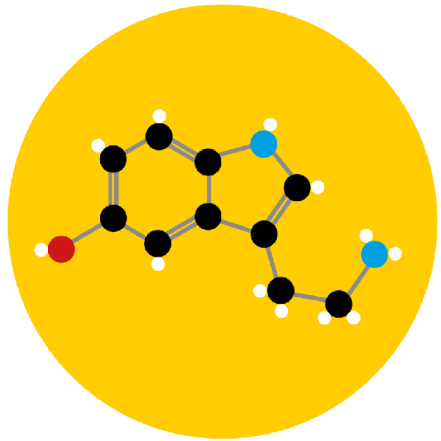
THE PLEASURE NEUROTRANSMITTER



Dopamine is associated with feelings of pleasure & satisfaction. It is also associated with addiction, movement, and motivation. The feelings of satisfaction caused by dopamine can become desired, and to satisfy this the person will repeat behaviours that lead to release of dopamine. These behaviours can be natural, as with eating and sex, or unnatural, as with drug addiction.

## SEROTONIN $C_{10}H_{12}N_2O$

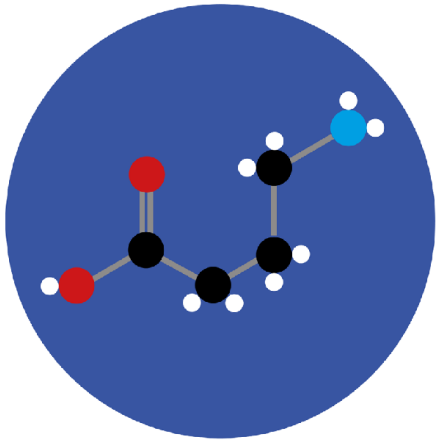
THE MOOD NEUROTRANSMITTER



Serotonin is thought to be a contributer to feelings of well-being and happiness. It regulates the sleep cycle along with melatonin, and also regulates intestinal movements. Low levels of serotonin have been linked to depression, anxiety, and some mental disorders. Antidepressants work by increasing serotonin levels. Exercise and light levels can also both have positive effects on the levels of serotonin.

## γ-AMINOBUTYRIC ACID $C_4H_9NO_2$

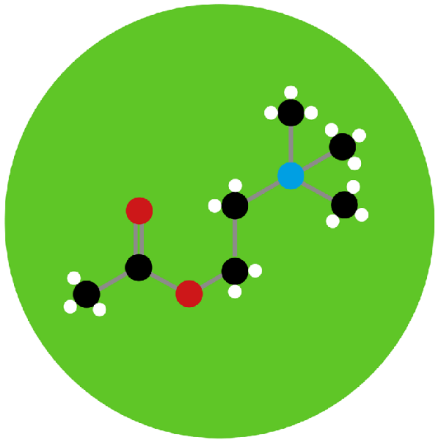
THE CALMING NEUROTRANSMITTER



Gamma-aminobutyric acid (GABA) is the major inhibitory neurotransmitter of the brain; its role is to calm firing nerves in the central nervous system. Increased levels improve mental focus and relaxation, whilst low levels can cause anxiety, and have also been linked with epilepsy. GABA also contributes to motor control and vision. Drugs to treat epilepsy often act by increaseing levels of GABA in the brain.

## ACETYLCHOLINE $C_7H_{16}NO_2^+$

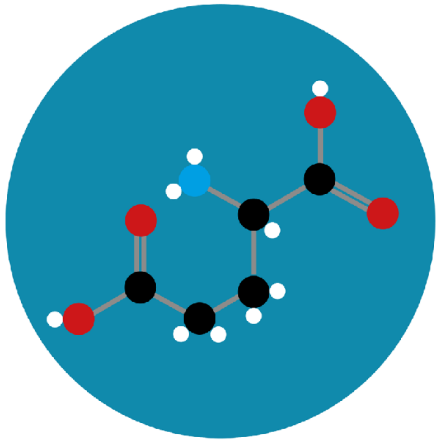
THE LEARNING NEUROTRANSMITTER



Acetylcholine, often shortened to ACh, is the principle neurotransmitter involved in thought, learning and memory. In the body, it is involved in activating muscle action. Damage to the acetylcholine producing areas of the brain has been linked with the memory deficits associated with Alzheimer's disease. Acetylcholine is also associated with attention, and enhancement of sensory perception upon waking.

## GLUTAMATE $C_5H_9NO_4$

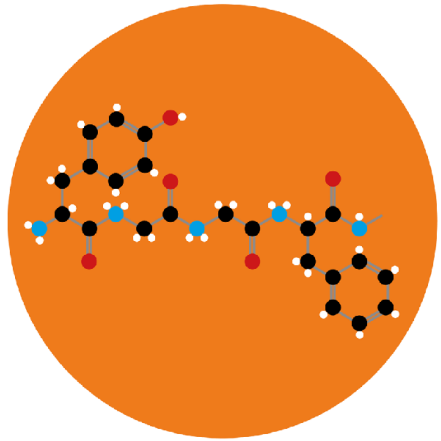
THE MEMORY NEUROTRANSMITTER



Glutamate is the most common neurotransmitter in the brain, and is involved in cognitive functions, such as learning and memory. It also regulates brain development and creation of nerve contacts. Glutamate is actually toxic to neurons in larger quantities, and if too much glutamte is present it can kill them; brain damage or strokes can lead to the creation of a harmful excess, killing brain cells.

## ENDORPHINS 20+ TYPES IN THE HUMAN BODY

THE EUPHORIA NEUROTRANSMITTERS



Endorphins are a range of compounds, the biologically active section of which is shown above, formed from long chains of multiple amino acids. They are released in the brain during exercise, excitement, pain, and sexual activity, and produce a feeling of well-being or even euphoria. At least 20 types of endorphins have been identified in humans. Certain foods, such as chocolate & spicy foods, can also stimulate the release of endorphins.

# NEUROTRANSMITTERS

over 100 NTs have been identified... most:

1. are synthesized under direction of the nucleus
2. are packaged in vesicles
3. are released from presynaptic axon terminal
4. cross synaptic cleft
5. bind to postsynaptic receptors - most can bind with several types of postsynaptic receptor, causing PSPs with varying parameters
6. are removed and/or degraded
7. back to step 1

# NEUROTRANSMITTERS

2 Main Classes of Neurotransmitters

- Small molecules
  - amino acids - building blocks of proteins (e.g., Glu / GABA)
    - all over the nervous system, global / local levels of excitation / inhibition
  - “biogenic amines” - “modulatory”, often confined to specific regions
    - 3 catecholamines (all synthesized from tyrosine)
      - Dopamine - DA
      - Norepinephrine (noradrenaline) - NE
      - Epinephrine (adrenaline) - E
    - 2 non-catecholamines
      - Serotonin (5 hydroxytryptamine) - 5-HT
      - Histamine - H
  - Acetylcholine - ACh
  - single ions (e.g., zinc)

# NEUROTRANSMITTERS

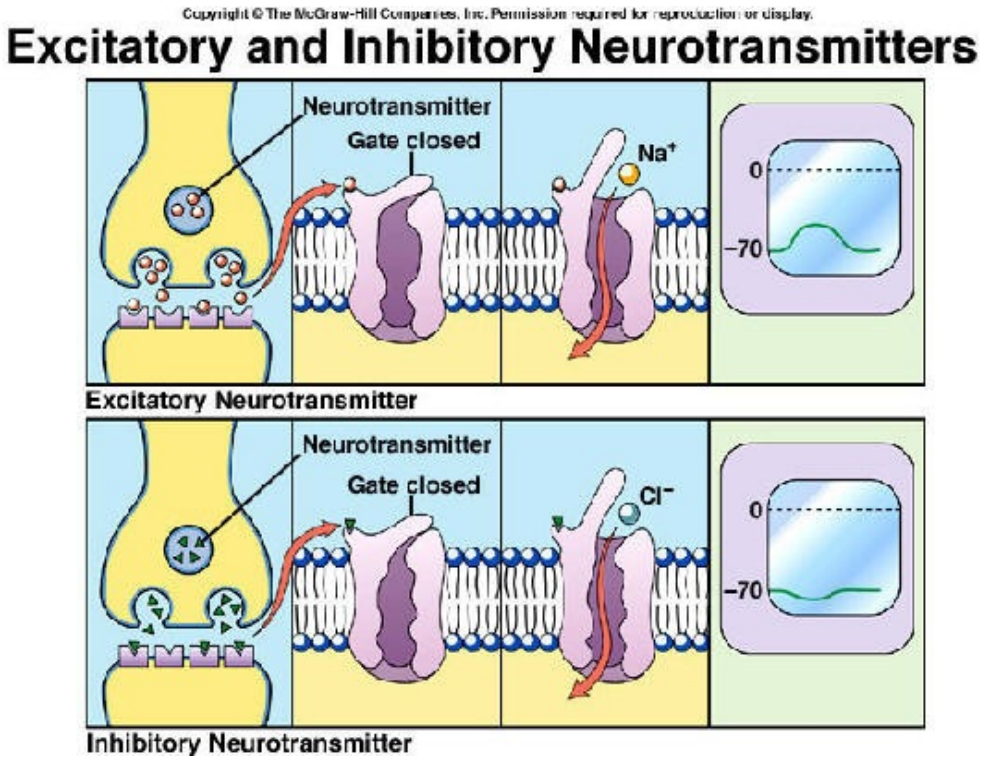
2 Main Classes of Neurotransmitters (cont)

- Large molecules
  - “neuropeptides” (proteins/fragments) - hormones, endorphins
    - modulatory (slow and fast)
    - often in the hypothalamus

- “Unconventional” (e.g. retrograde signals) - fatty acids (anandamide), gases (NO)

# NEUROTRANSMITTERS

- AMINO ACIDS
  - main “excitatory” NT is the amino acid *glutamate*
    - *Generally lets Na+ in*
  - main “inhibitory” NT is the amino acid gamma-aminobutyric acid *(GABA)*
    - *Generally lets Cl- in or K+ out*
- Location is ubiquitous
- Several subtypes of each (e.g., NMDA, GABAa)
  - Some ionotropic / some metabotropic
- Removed from synapse by presynaptic and/or glial uptake



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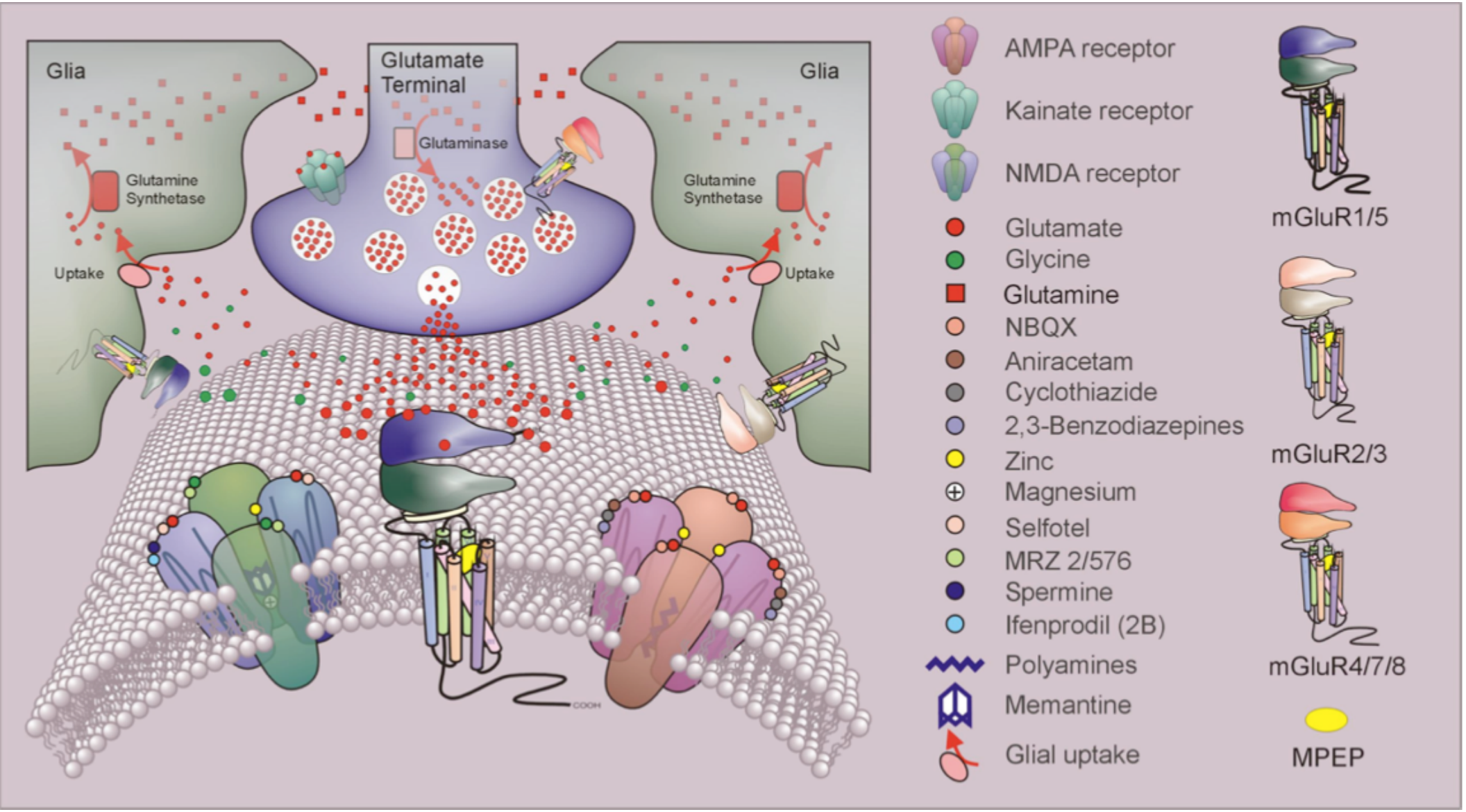
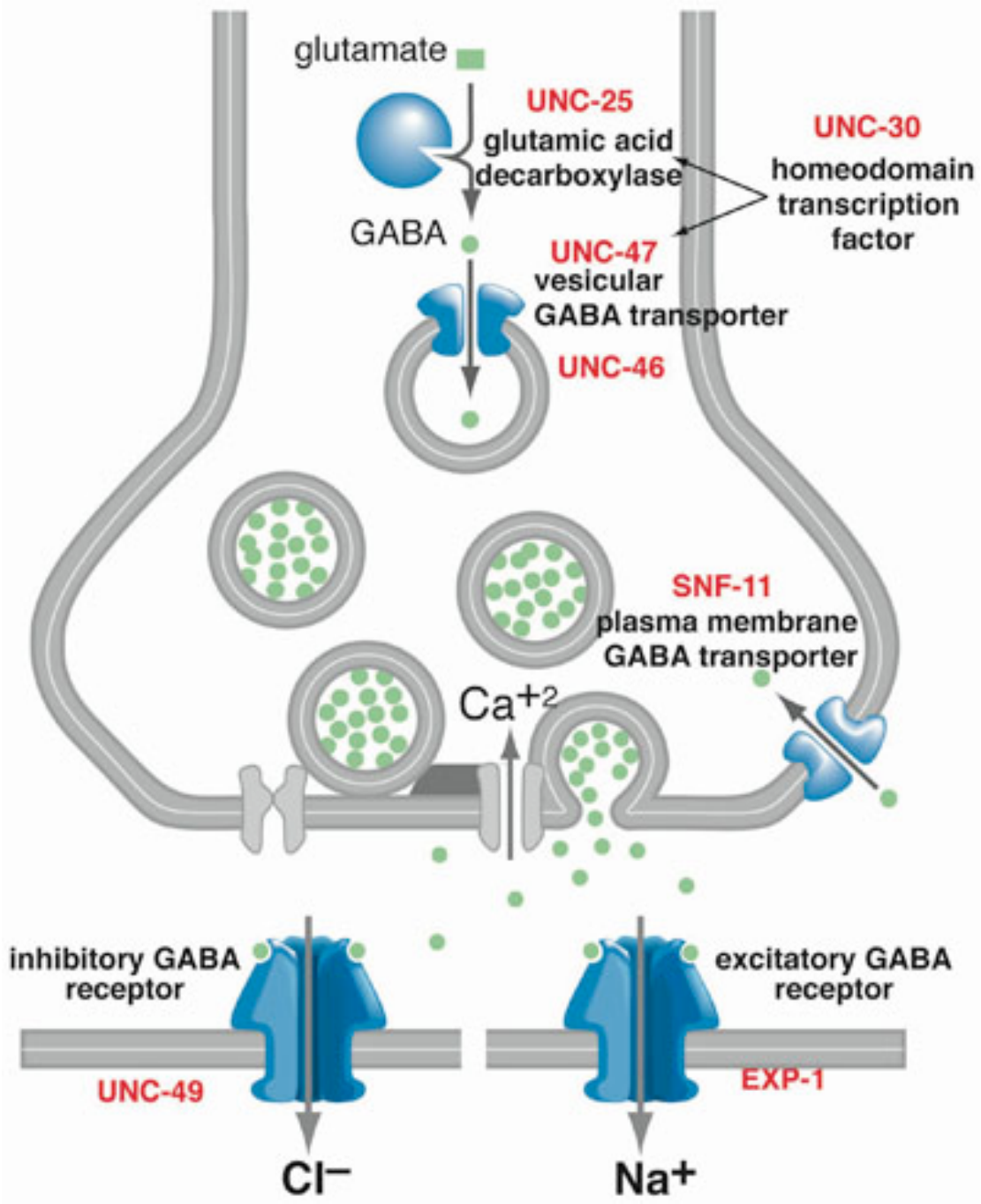


# NEUROTRANSMITTERS

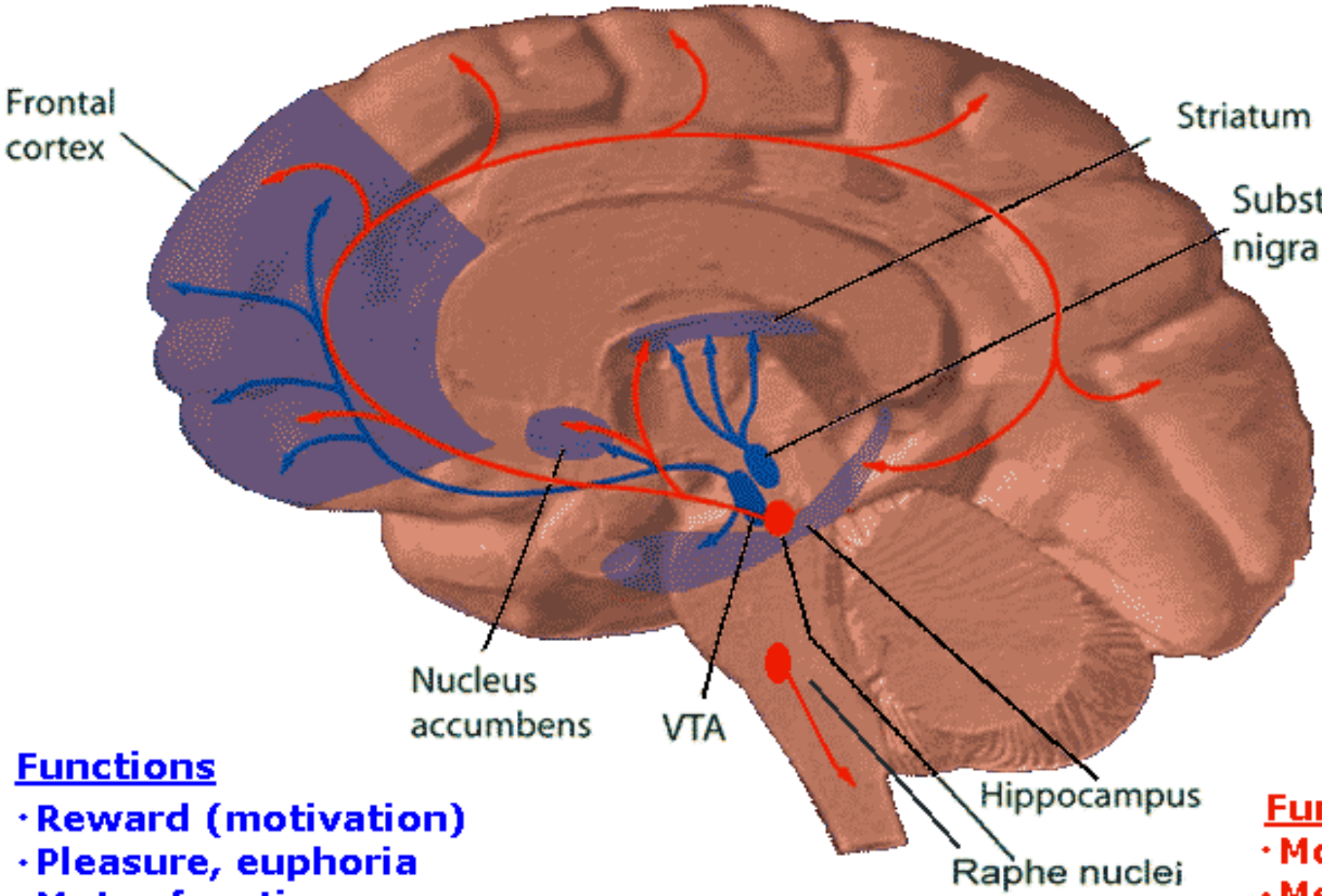


# NEUROTRANSMITTERS

- The Big 4 modulators - each is present at “baseline levels” in specific regions that can be quickly adjusted up / down - ratio of each is often most important
  - Dopamine (DA)
  - Epinepherine (E; aka adrenaline, also NE)
  - Serotonin / 5-hydroxytryptamine (5HT)
  - Acetylcholine (ACh)

## Dopamine Pathways

## Serotonin Pathways

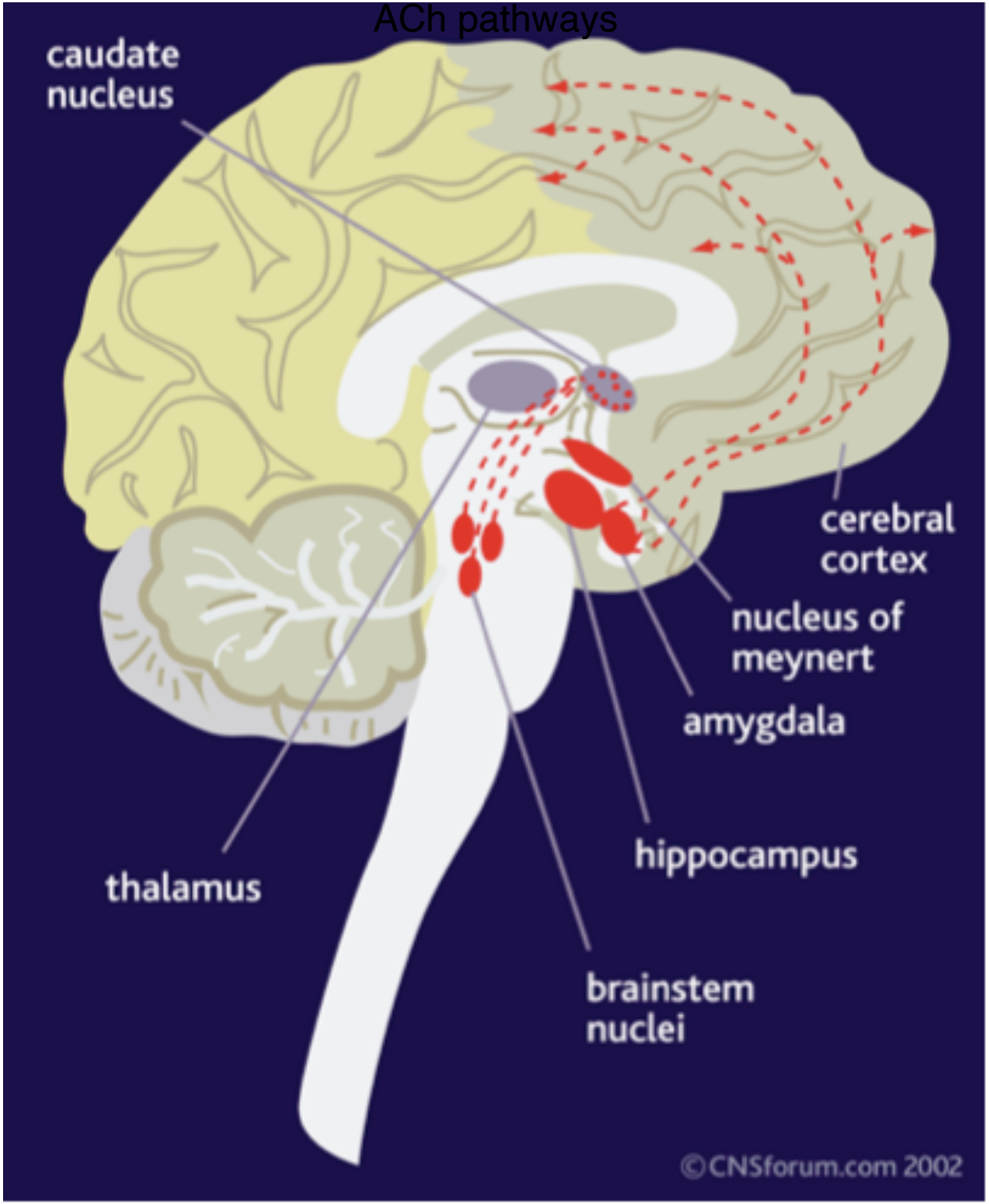



**Functions**

- **Reward (motivation)**
- **Pleasure, euphoria**
- **Motor function (fine tuning)**
- **Compulsion**
- **Perseveration**

**Functions**

- **Mood**
- **Memory processing**
- **Sleep**
- **Cognition**


ACh pathways
caudate nucleus
cerebral cortex
nucleus of meynert
amygdala
hippocampus
thalamus
brainstem nuclei
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# NEUROTRANSMITTERS

- The Big 4 (cont)
  - Dopamine (DA) - made in basal ganglia + other areas near top of brainstem
    - Associated with:
      - focus / energy / pursuit of goals
      - craving / motivation / drive
        - Not necessarily “pleasure”
  - Epinepherine (E; aka adrenaline, also NE) - made in brainstem (locus ceruleus +)
  - Similar circuits / derived from DA
    - E made in kidneys does not reach brain
    - Increased “energy”

# NEUROTRANSMITTERS

- The Big 4 (cont)
  - Serotonin / 5-hydroxytryptamine (5HT) - generally made in brainstem
    - contentment / soothed / happy / satiety (“enough”)
      - tends to inhibit DA circuits
  - Acetylcholine (ACh) - made basal forebrain
    - states of focus related to learning / “opening up” / increased neuroplasticity
      - High energy but calm

# NEUROTRANSMITTERS

- Ratios of these change throughout day
  - Waking hours:
    - 1st half - DA / E are highest
    - 2nd half - DA / E decline, 5HT rises
      - ACh is context dependent during waking
  - Sleeping hours - DA / 5HT / ACh cycle wildly
    - Not so much w/ E - increases associated w/ waking up

# NEUROTRANSMITTERS

- Role of hormones (“large molecule” / neuropeptides)
  - Rapid fx (e.g. adrenaline increases heart rate)
  - Slow fx (e.g., gene expression > puberty)

- In general, tend to act in concert w/ the NTs
  - testosterone <-> dopamine
  - cortisol <-> epinepherine
  - prolactin / oxytocin <-> serotonin

  - acetylcholine not tied strongly to any hormone

# NEUROTRANSMITTERS

- Manipulating the neuromodulators:
    1. Nutrition
    2. Behaviors
    3. Dietary supplements
    4. Drugs

# NEUROTRANSMITTERS

- Dopamine (DA)
  - Generally maximize by:
    - eating tyrosine-containing foods
    - exposure to sunlight as soon as you wake
  - Rapidly increase:
    - dietary supplements
    - cold exposure
    - non-sleep deep rest states (e.g., meditation) ?
    - stimulants

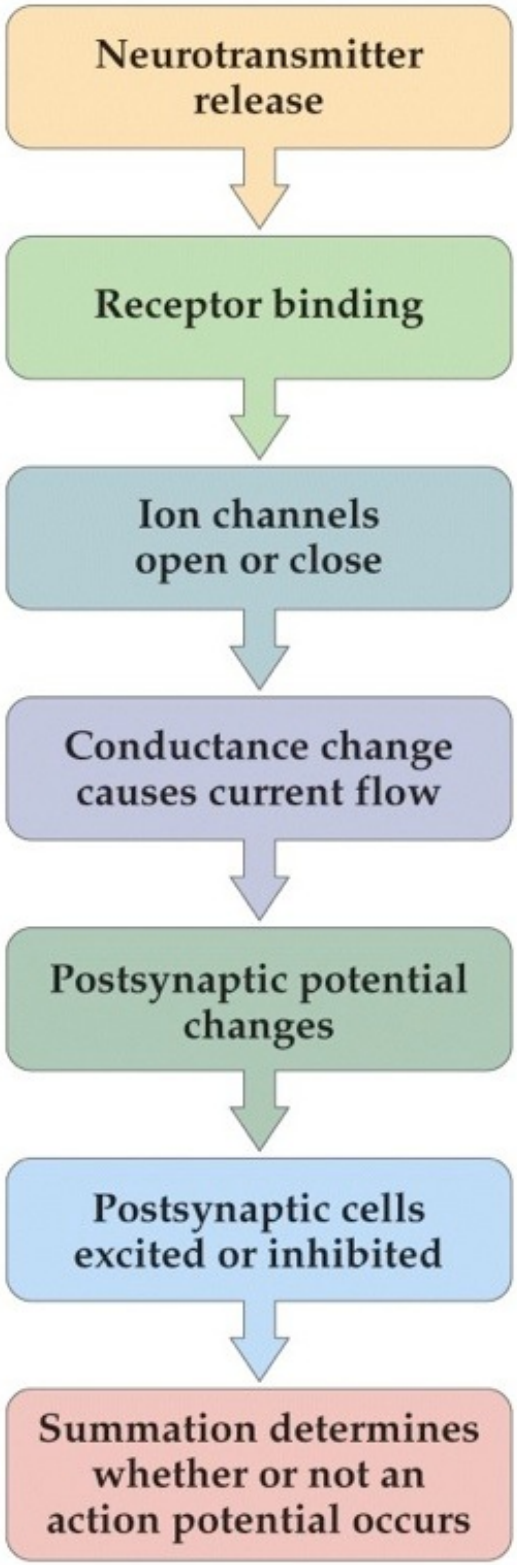
# NEUROTRANSMITTERS

- Epinepherine (E; aka adrenaline)
  - Rapidly increase w/
    - Exercise / breathing techniques (e.g., hyperventilation) / cold exposure
    - Decrease w/ beta-blockers

- Serotonin / 5-hydroxytryptamine (5HT)
  - Maximize w/ tryptophan-rich foods (whole milk, etc)
  - Rapidly increase - gratitude (receiving more than giving), cuddling

# NEUROTRANSMITTERS

- Acetylcholine (ACh)
  - Maximize w/ choline-rich foods (eggs, etc)
  - Rapidly increase (to increase focus) w/ dietary supplements, nicotine (gum?)


Neurotransmitter release
Receptor binding
Ion channels open or close
Conductance change causes current flow
Postsynaptic potential changes
Postsynaptic cells excited or inhibited
Summation determines whether or not an action potential occurs