Electrical Synapses

- Exist between neurons or neurons + glial cells
- Plasma membranes are linked by gap junctions that ions and second messenger molecules can move through
- located in the retina and eye cortex, regulate breathing in the brainstem

Chemical Synapses

1) action potential reaches the axon terminal and calcium channels open → calcium flows into the axon terminal (increases cytosolic calcium concentration)
2) membranes of synaptic vessicles fuse with vessicle attatchment sites
3) undergoes exocytosis to release neurotransmitters into the synaptic cleft
4) neurotransmitters diffuse toward postsynaptic neuron + bind to receptors → induces a response in the neuron

- Extra neurotransmitters can be degraded by enzymes, transported back to the presynaptic neuron to be recycled (reuptake), or diffuse out of the cleft
- Signal Transduction Mechanisms
  - Fast response occurs when a NT binds to a channel-linked receptor (ionotropic receptor) → allows ions to permeate plasma membrane, causing postsynaptic potential (change in membrane potetial
  - Slow responses are mediated through G protein-linked (metabotropic) receptors → trigger open/closing of ion channels → triggers activation/inhibition of a second messenger system
- Excitatory synapses: brings the membrane potential closer to the action potential threshold
  - Fast excitatory postsynaptic potentials (EPSP) are caused by NT binding to receptors + opening channels to let cations (Na^+ and K^+) through → more Na^+ move in than K^+ move out → net depolarization
  - Slow EPSP are caused by closing of K^+ channels by cAMP: NT binds to receptor + activates G protein → activates adenylate cyclase enzyme to catalyze [ATP → cAMP] → cAMP activates protein kinase A that catalyzes a phosphate group in the K^+ channel → Phosphorylation of K^+ channel closes it
- Inhibitory Synapses:

- inhibitory postsynaptic potential (IPSP): hyperpolarization when NT bind to more receptors + open mor K^+ channels

- Stabilize MP at less than the threshold: Cl^- channels open, Cl^- moves into the cell, producing hyperpolarization

Neural Integration

- neural integration: summation of all signals arriving from all active synapses → an action potential is triggered if the MP at the axon hillock is depolarized to threshold

- temporal summation: postsynaptic potentials overlapping → resulting de/hyper-polarization is larger than for a single potential
  - can occur b/c postsynaptic potential takes longer than an AP → presynaptic neuron can release 2nd AP before NT leave the cleft

- Spatial summation: occurs when postsynaptic potentials originating at different synapses spread to the axon hillock, overlapping

- Frequency coding: strength of suprathreshold stimuli ∝ Frequency of action potentials ∝ # of neurotransmitters released

Presynaptic Modulation

- modulatory synapses: axoaxonic synapses → synapses that regulate communication across another synapse
  - in axoaxonic synapses, NT don't generate electrical signals, but bind to receptors on the axon terminal + induce change of amount of calcium → alters # of NT released from postsynaptic neuron

- Presynaptic Facilitation: release of a NT is enhanced, inhibition: release of NT is decreased

Neurotransmitters

- Acetycholine (ACh): most abundant NT in peripheral NS. Synthesized in cytosol from acetyl CoA and choline by Choline acetyl transferase acetyl CoA + choline $\xrightarrow{CAT}$ acetylcholine + CoA can bind to cholinergic receptors, or broken down by acetylcholinesterase (AChE) enzyme

- nicotinic cholinergic receptors → ionotropic + triggers opening to let Na^+ and K^+ travel → causes an EPSP

- muscarinic cholinergic receptors → metabotropic receptors that operate through action of G proteins

- Biogenic Amines: dopamine + norepinephrine are released by neurons in the CNS, epinephrine is mostly a hormone released from the adrenal medulla in the sympathetic NS

- epinephrine → highest affinity for $beta_2$ adrenergic receptors, norepinephrine → alpha + beta.
- Catecholamines produce slow responses through G proteins + bind to autoreceptors. They can be degraded by monoamine oxidase (MAO → in the synaptic cleft + mitochondria of axon terminals + glial cells) and cate-o-methyltransferase (COMT → synaptic cleft)

- Seritonin → found in CNS, brainstem, regulates sleep + emotions, Histamine → CNS, hypothalamus, releases from non-neural cells during allergic reactions or as a neurotransmitter

- **Amino Acid Neurotransmitters:** most abundant in the CNS
  - Glutamate: most commonly released NT at exitatory synapses in CNS (asparate too)
  - GABA: released at inhibitory synapses. $GABA_C$ receptors located in the retina
- **Purines:** ATP, ADP, Adenosine
- **Neuropeptides:** known as hormones → TRH, vasopressin, oxytocin, substance P, cholecytokinin, endogenous opioids (endorphines)
- **Others:** nitric oxide, endocannabinoids