Biopsychology 2012 – sec 003 (Dr. Campeau)

Study Guide for First Midterm

What are some fun facts about the human brain?

- there are approximately 100 billion neurons in the brain;
- each neuron makes between 1000 to 10000 connections with other neurons;
- speed of action potentials varies from less than 1 mph and up to 100 mph.

What is a neuron?

A very specialized cell type whose function is to receive, process, and send information; these cells are found in the central nervous system (CNS – brain, spinal cord, retina) and the peripheral nervous system (PNS – the rest of the body).

What is a nerve?

They are axons of individual neurons in bundles or strands of many axons.

What are the major parts of a neuron?

- cell membrane: "skin" of the neuron;
- cytoplasm: everything inside the skin;
- nucleus: contains chromosomes (DNA);
- ribosomes: generate proteins from mRNA;
- mitochondria: energy "generator" of cells (produce ATP);
- mitochondria: moves "stuff" inside the neuron (like a tow rope);
- soma: cell body, excluding dendrites and axons;
- dendrites and spines: part of the neuron usually receiving information from other neurons;
- axons: part of the neuron that transmits information to other neurons;
- myelin sheath: surrounds axons and provides electrical "insulation";
- nodes of Ranvier: small area on axons devoid of myelin sheath;
- presynaptic terminal: area of neuron where neurotransmitter is stored and released by action potentials.

What are the different neuron types according to function?

1. Sensory neurons: neurons specialized to "receive" information about the environment.
2. Motor neurons: neurons specialized to produce movement (contraction of muscles).
3. Interneurons or Intrinsic neurons: neurons, usually with short axons, that handle local information.

What are the different neuron types according to structure?

1. Multipolar neurons: more than two processes extending from cell body.
2. Bipolar neurons: two processes extending from the cell body.
3. Pseudounipolar neurons: only one process extending from the cell body.

What is a synapse?

"gap" between the presynaptic terminal and the postsynaptic terminal (the neuron it is trying to "talk" to).

What are the different parts of a synapse?

- synaptic vesicles;
- pre-synaptic membrane;
- synaptic cleft;
- post-synaptic membrane;
- post-synaptic receptors.

What are some of the different types of synapses based on structure?

1. Axo-dendritic: axon contacts dendrites of post-synaptic neuron.
2. Axo-somatic: axon contacts soma of post-synaptic neuron.
3. Axo-axonic: axon contacts axons of post-synaptic neuron.

What are the different types of synapses based on neurotransmitter and/or post-synaptic receptors?

Examples include
- GABA
- Glutamate
- Adrenergic
- Peptidergic

What are the supporting cells (glial cells) of the nervous system?

1. Oligodendrocytes: cells that form myelin sheat in the central nervous system.
2. Schwann cells: cells that form myelin sheat in the peripheral nervous system.
3. Astrocytes: provides structural support, nutrients and regulates chemical environment.
4. Microglia: acts as phagocytes to protect brain from infecting microorganisms.
5. Ependyma: epithelial cells lining the ventricles and other cavities around the brain, acting as a barrier.

What is the main function of neurons?

Main purpose of neurons is to receive, process, and send messages.

What are the neuron's characteristics that allow communication?

1. The resting membrane potential, and;
2. The action potential.

What is the resting membrane potential?

It is a potential (electrical charge) difference across the neuron's membrane (lipid bilayer) produced by the semi-permeable property of the membrane, which keeps the inside of the neuron negative, relative to the outside. The semi-permeable membrane property keeps ions (cations: positively charged ions, sodium and potassium; anions; negatively charged ions, chloride and negatively charged proteins) mostly inside or outside of the neuron. At rest, potassium and protein anions are in high concentration inside the neuron while sodium and chloride are in high concentration outside the neuron. The resting membrane potential in living neurons is approximately -70 mV.

What are the forces that help maintain and restore the resting membrane potential?

1. Passive forces (uses no energy): Diffusion (concentration gradients) and electrostatic pressure (opposite attracts, similar repulse);
2. Active transport (uses energy - ATP): Sodium/potassium ionic pump.

How are action potentials produced?

1. Neurotransmitters are released in synapse;
2. Neurotransmitters bind to post-synaptic receptors;
3. Binding of neurotransmitters opens ion channels, which produce:
   - EPSP: excitatory post-synaptic potentials (sodium goes in – makes action potential more likely to be produced), or
   - IPSP: inhibitory post-synaptic potentials (potassium goes out, or chloride goes in – makes action potential less likely to be produced);
4. EPSPs and IPSPs are graded potentials, **not** action potentials;
5. Graded potentials travel passively and very fast toward the cell body;
6. Graded potentials are integrated (summation) via both:
   - *Spatial summation*: graded potentials from different synapses, and
   - *Temporal summation*: graded potentials produced close in time;
7. If summation reaches threshold voltage, an action potential is triggered at axon hillock.
8. Once threshold voltage is reached, voltage-dependent sodium channels snap open; they close near the peak of the action potential (around +30 to +40 mV);
9. Voltage-dependent potassium channels snap open near the peak of the action potential to help restore resting membrane potential; they close as membrane potential approaches the resting membrane potential (-70 mV);
10. The "action potential" is regenerated via this active process at every patch of membrane going down the axon all the way to the pre-synaptic terminals, where it produces neurotransmitter release to "talk" to the next neuron.

What is the refractory period?

It is a "rest" period after an action potential when it is impossible to produce another action potential (absolute refractory period), or when it is harder to produce an action potential (relative refractory period).

What are the laws of conduction of action potentials?

1. *All-or-none law*: An action potential is either produced or not produced; if it is produced it is always the same strength, there are **no intermediate** action potentials.

2. *Rate law*: The strength of stimuli affects the rate of firing; a strong stimulus produces more action potentials than a weak stimulus; but the amplitude of each action potential is the same.

What is saltatory conduction?

Conduction of action potentials in myelinated axons, where the action potential "jumps" from one node of Ranvier to the next. It allows for more rapid action potential conduction and requires less energy.

Where are neurotransmitters produced?

1. Small neurotransmitter molecules are synthesized in the terminal buttons via synthetic enzymes and precursor molecules (ex., acetylcholine).
2. Larger neurotransmitters (peptides) are synthesized in the cell body on ribosomes from mRNA precursors and transported down the axons to the terminal buttons (ex., enkephalin).
3. Both small and large neurotransmitters are packaged into synaptic vesicles (there is normally only one type of neurotransmitter that gets packaged into a single vesicle)

How are neurotransmitter released from the presynaptic buttons?

1. Action potential invades presynaptic terminal;
2. This opens voltage-sensitive calcium channels;
3. Calcium enters into the presynaptic button;
4. Calcium induces the "docking" and "fusion" of synaptic vesicles to the presynaptic membrane;
5. The synaptic vesicles open into the synaptic cleft and release neurotransmitters into the cleft.

How are neurotransmitters deactivated when they are released in the synapse?

1. They are reuptaken into the presynaptic button or glial cells via specific transporters.
2. They are degraded by specific enzymes.
3. Once degraded, they can be recycled (precursors used to make new neurotransmitters).

What are neurotransmitter receptors?

They are proteins that are inserted into the membrane and contain binding sites for neurotransmitters.

How do receptors recognize neurotransmitters?

Receptors recognize specific neurotransmitters much like a lock and key arrangement; neurotransmitters are the keys that fit into specific locks (receptors).

What determines the effects of specific neurotransmitters?

It is determined by the postsynaptic receptors. If neurotransmitter is released but not postsynaptic receptors to respond to it, nothing happens.

What are the different types of receptors based on function?

1. Ionotropic: binding of neurotransmitters opens ion channel.
2. Metabotropic: binding of neurotransmitters induces the production of "second-messenger" molecules, which can:
   - open or close ion channels;
   - produce metabolic effects;
   - act on gene regulation in nucleus.

What are the different types of receptors based on location?

1. Postsynaptic receptors;
2. Presynaptic receptors (heteroreceptors): respond to different neurotransmitters;
3. Presynaptic receptors (autoreceptors): respond to its own neurotransmitter.

What are the 7 criteria used to determine neurotransmitter status?

1. Isolation from presynaptic neuron;
2. Enzymes for production and destruction;
3. Released from presynaptic button;
4. Action on postsynaptic neuron (i.e., produce EPSP or IPSP);
5. Postsynaptic receptor sites;
6. Deactivation – Reuptake or degradation;
7. Predictable pharmacological action.

What are the major classes of neurotransmitters and some of their functions?

I. Small molecule transmitters:

A. Acetylcholine (precursors: choline and acetyl-coenzyme A):
- contracts skeletal muscles; neuromuscular junction;
- parasympathetic nervous system.

B. Monoamines:

A. Catecholamines:

i. Dopamine (precursor: tyrosine):
- movement, attention, learning, reward;
- degeneration of Substantia Nigra in midbrain = Parkinson's disease;
- schizophrenia

ii. Norepinephrine and epinephrine (adrenaline):
- released by sympathetic nervous system and adrenal glands;
- control alertness/wakefulness; alarm reactions.

B. Indolamines:

Serotonin (precursor: tryptophan):
- control of eating, sleep, and arousal;
- inhibits dreaming.

C. Amino acids:

1. Excitatory amino acids (ex., glutamate, aspartate):
- excitatory neurotransmitters producing EPSPs.

2. Inhibitory amino acids:

i.Gamma-aminobutyric acid (GABA):
- inhibitory neurotransmitter producing IPSPs;
- degeneration in basal ganglia = Huntington's chorea.

ii. Glycine:
- inhibitory neurotransmitter;
- normally inhibits motor neuron activity;

II. Large molecule transmitters:

Neuropeptides: small amino acid peptides
- diverse types and functions:
- endorphins (endogenous opiates – inhibit pain).

III. Soluble gases: small molecules with very different neurotransmitter properties:
- produced in cytoplasm by enzymes and diffuses freely across lipid membrane to neighboring neurons

1. Nitric oxide:
- regulates vascular relaxation;
- involved in learning and memory.

2. Carbon monoxide:
- regulates vascular relaxation (in combination with nitric oxide);
- regulates peristaltic relaxation (intestinal movement).

What are the synthetic and metabolic pathways for the neurotransmitter Acetylcholine:

Requires the presence of Acetyl-Coenzyme A and Choline; the enzyme choline acetyltransferase (ChAT) produces the catalysis of Acetyl-CoA and attaches the acetyl group to

Choline, thus producing Acetylcholine (ACh). Upon release into the synaptic cleft, ACh is broken down by the enzyme acetylcholinesterase (AchE) into choline and an acetate ion. Some of these products can be taken back up the presynaptic terminal to produce ACh.

What is the synthetic pathway for all three Catecholamines?

- the precursor amino acid *tyrosine* is broken down by tyrosine hydroxylase to produce L-Dopa
- in turn L-Dopa is transformed to *dopamine* by the enzyme DOPA decarboxylase;
- dopamine can be further processed by dopamine • -hydroxylase to produce *norepinephrine*;
- finally norepinephrine can be transformed to *epinephrine* by the additional enzyme phenylethanolamine-N-methyl-transferase.

What is psychopharmacology?

The study of the effects of drugs on the nervous system and on behavior.

What is a drug?

An *exogenous* chemical not necessary for normal cellular functioning that significantly alters the functions of certain cells of the body when taken in relatively low doses (in this context, cells of the nervous system).

What is exogenous? A compound produced outside the body (ex., aspirin).
What is endogenous? A compound produced in the body (ex., acetylcholine).

What is a drug effect?

The changes observed in an organism's physiological processes and behavior.

Note: The terms "Drug" and "Ligand" are often used interchangeably in pharmacology.

What effects do drugs have?

Drugs produce one of two effects; they either facilitate or inhibit neurotransmission.

What is an agonist drug? A drug that facilitates the effects of a particular neurotransmitter.
What is an antagonist drug? A drug that inhibits the effects of a particular neurotransmitter.

What are the different sites of drug action?

A. For agonists: facilitate synaptic transmission

1. Acts as precursor (ex. L-dopa – dopamine);
2. Causes synaptic release (ex. black widow venom – ACh);
3. Stimulates receptors (ex. nicotine – ACh);
4. Inhibits autoreceptors (ex. clonidine – norepinephrine);
5. Inactivates degradation enzyme (ex. physostigmine – ACh);
6. Blocks reuptake (ex. prozac – serotonin).

B. For antagonists: inhibit synaptic transmission

1. Inactivates synthetic enzyme (ex. PCPA – serotonin);
2. Prevents synaptic release (ex. botulinum toxin);
3. Makes synaptic vesicles leaky (ex. reserpine – monoamines);
4. Blocks postsynaptic receptors (ex. curare – ACh);

5. Stimulates autoreceptors (ex. LSD – serotonin).

How are drugs administered?

There are several routes of administration depending on the structure of the drug and the speed with which the drug is needed.

- intravenous (most rapid drug delivery for soluble drugs);
- oral (relatively slow delivery for drugs that are not broken down in the stomach or intestines);
- inhalation (relatively rapid drug delivery for gaseous compounds);
- intramuscular (relatively slow drug delivery for substances soluble in oils);
- subcutaneous; sublingual; rectal.

What is ED_{50}? Dose of drug at which 50% of maximal effect is achieved.
What is LD_{50}? Dose of drug at which 50% lethality is observed.
What is the <u>therapeutic index</u>? Ratio of LD50/ED50 (larger is better = safer drug).

What is a drug's <u>potency</u>? Dose of drug required to observe an effect; it is related to the "affinity" of a drug for its site of action.

What is a drug's <u>efficacy</u>? It is related to the maximal effect of the drug.