A&P 2
Nervous System

FUNCTIONS
1) Sensory input – stimuli
2) Integration - process and interpret
3) Motor output - activates effector organs
"stop light"
"taste food “

ORGANIZATION

CENTRAL NERVOUS SYSTEM (CNS)
brain, spinal cord
- integration
- command center

PERIPHERAL NERVOUS SYSTEM (PNS)
cranial nerves, spinal nerves
- communication lines

SOMATIC NERVOUS SYSTEM (SNS)
Sensory neurons convey information from cutaneous and special sense organs, body wall and limbs to the CNS
Motor neurons that conduct impulses from CNS to skeletal muscle only
"voluntary"

AUTONOMIC NERVOUS SYSTEM (ANS)
Sensory neurons convey information from receptors in viscera to CNS
Motor neurons that conduct impulses to smooth muscle, cardiac muscle and glands
"involuntary"

BRANCHES OF ANS
<u>Sympathetic</u>
- involves expenditure of energy

<u>Parasympathetic</u>
- restores or conserves energy

ANS BRANCHES
two divisions have opposing actions
- ex: sympathetic speed up heart rate
- parasympathetic slows down heart rate

NERVE TYPES
1) neurons
- sense
- think
- remember
- regulate gland function
- control muscle movement

2) neuroglia
- support neurons
- nurture neurons
- protect neurons

NEUROGLIA
"glia cells"
Support neurons
More numerous than neurons
Make up half the mass of the brain
Able to multiply and divide
Multiply and fill in areas of neurons that are destroyed by injury
Brain tumors commonly arise from glia cells and are highly malignant

NEUROGLIA TYPES
<u>CNS</u>
astrocytes
microglia
oligodendrocytes
ependymal cells
<u>PNS</u>
neurolemmocytes
satellite cells

ASTROCYTES
"nursing neurons"
Many processes
Maintain proper balance of K+ for generation of nerve impulse
Participate in neurotransmitter metabolism
Participate in brain development by assisting migration or neurons
Provides link between neurons and blood vessels
Form blood-brain barrier (BBB)
Regulate entry of substances into brain
BLOOD BRAIN BARRIER
BBB allows diffusion only of lipid soluble substances across the astrocyte membrane surrounding the capillary
    Nicotine, ethanol, heroin
    Water soluble substances may pass but only by mediated transport
    Glucose, amino acids
PARKINSON'S DISEASE
caused by a lack of the neurotransmitter dopamine
normally produced by neurons of the brain
Lack of dopamine causes the characteristic shaking and decreased muscle control
Administration of dopamine is not helpful because it cannot cross the BBB
Administration of L-dopa (a precursor of dopamine)
    reduces the symptoms because it can pass the BBB and is converted to dopamine by the CNS neurons
MICROGLIA
Small, phagocytic
Derived from monocytes
engulf bacteria
clear away debris from dead cells
may migrate to areas of injured nerve tissue
OLIGODENDROCYTES
Most numerous glial cell
Support neurons by twining around them and producing a lipid protein wrap called a myelin sheath
Each oliodendrocyte wraps myelin around several axons
EPENDYMAL CELLS
Derived from epithelial cells
Many may be ciliated
Line the fluid filled ventricles of the brain
Form cerebrospinal fluid (CSF) and assist its circulation
NEUROLEMMOCYTES
"Schwann cells"
produce myelin sheaths around PNS neuron axons
each cell produces part of the myelin sheath around a single axon of a PNS neuron
SATELLITE CELLS
support neurons in ganglia clusters of the PNS
NEURONS
various sizes and shapes
the basic functions of all neurons are more or less similar
1) receive and integrate inputs
    2) relay their output to some other target cell
cell that has an excitable cell membrane
capable of producing an electrical impulse
communication between neurons
passing of a chemical message from one nerve cell to another across space between them called the synapse

NEURON ANATOMY

1) Soma
   - Nissl bodies
   - Nucleus

2) Dendrites

3) Axon
   - neurolemma
   - Schwann cell
   - Node of Ranvier

4) Synapse
   - synaptic knob
   - synaptic cleft
   - synaptic vesicles

SOMA (Cell body)

lack spindle fibers necessary for cell division
acts as a bridge between the dendrite and the axon
site of an extremely high rate of metabolism
numerous mitochondria, ribosomes and endoplasmic reticulum

NISSL BODIES

clusters of ER and ribosomes

GANGLIA AND NUCLEI

grouped soma having similar functions
   - <u>ganglia</u> (along spinal cord)
   - <u>nuclei</u> (within CNS)

DENDRITES

short, branched arms that stick out from the soma
receive incoming signals and carry them to the soma
cell membrane of soma and dendrites sensitive to chemical, mechanical or electrical stimulation
stimulation leads to generation of action potential (nerve impulse) conducted along the axon

AXON

conduct impulse away from the soma
   - neurolemma

Schwann cell
Node of Ranvier

NEUROLEMMA

axonal membrane found only in myelinated neurons
primarily in peripheral nervous system

SCHWANN CELL

cells that wrap around the axons of nerves
form myelin
a fatty protein sheath
whitish in color
acts as an electrical insulator
increase the speed and efficiency at which nerve impulses may be transmitted

NODE OF RANVIER

gaps located between neighboring Schwann cells on myelinated neurons
nerve transmission occurs at the node (gap) only
skips over the insulated portion of the axon
the current jumps from node to node

SYNAPSE

gap that acts as a junction between axon of presynaptic neuron and dendrite of postsynaptic neuron
presynaptic axon ends in <u>synaptic knob</u>

SYNAPTIC KNOB

contains numerous mitochondria and synaptic vesicles full of neurotransmitters
neurotransmitters act to excite or inhibit neighboring neurons

SYNAPTIC CLEFT

short distance between synaptic knob and postsynaptic dendrite is very small
place for regulation of transmission
If a signal is too weak, it will not traverse the synaptic gap
If the signal is strong enough, it will go on to excite the postsynaptic membrane, and thereby continue the transmission
many drugs that act on the nervous system interfere with activity in the synaptic cleft

FUNCTIONAL CLASSIFICATION OF NEURONS
1) Sensory neurons
receptors
2) Motor neurons
effectors
3) Interneurons
SENSORY NEURONS
app. 10 million sensory neurons in body
also known as afferent fibers
carry info from receptors to central nervous system
RECEPTORS
may be a process of a sensory neuron
may be a specialized cell which communicates with a sensory neuron
<u>Extroreceptors</u>
touch, temperature, pressure, sight, smell, touch, hearing
<u>Proprioreceptors</u>
monitor position of skeletal muscles and joints
<u>Interoreceptors</u>
monitor the activities of the viscera, taste, pain
MOTOR NEURONS
app. 1/2 million motor neurons in body
also known as efferent fibers
carry signals from the CNS to the effector organs (muscles and glands)
EFFECTORS
peripheral targets of motor neurons
change their activities in response to motor neuron impulse
skeletal muscle, cardiac muscle, smooth muscle, glands
INTERNEURONS
app. 20 billion interneurons in body
located entirely within the CNS
interconnect other neurons
analysis of sensory input
coordination of motor output
MYELINATION
most neuron axons are surrounded by a <u>myelin sheath</u>
protein lipid covering produced by neuroglia
1) electrically insulates axon
2) speeds up the transmission of nerve impulse through the axon
WHITE MATTER
the major component of a cell membrane is the phospholipid bilayer
many layers of membrane stacked on top of one another creates a fatty appearance due to the presence of this phospholipid
lipid has a glistening white appearance
such as fat found on meats
myelinated axons have a glistening white appearance
GRAY MATTER
areas containing mainly cell bodies tend to lack myelin
NEUROLEMMA
neurolemmocytes (Schwann cells) wrap several times around a small portion of the PNS axon
myelin sheath is called a <u>neurolemma</u>
aids regeneration of an axon if it is injured
forms a regeneration tube that guides and stimulates regrowth of the axon
NODES OF RANVIER
Intervals along the axon where there are gaps between the myelin sheath
Neurolemmocytes wrap (neurolemma) the axon segment between the two nodes
oligodendrocytes myelinate many cells of the CNS in much the same manner as a neurolemmocyte myelinates parts of a single PNS axon
CNS LACKS NEUROLEMMA
many broad flat processes spiral about CNS axons and deposit a myelin sheath
neurolemma is not formed
axons in the CNS display little regrowth after injury
due to absence of neurolemma and inhibitory influence exerted by CNS neuroglia

MYELIN AND NERVE REGENERATION
possible only if the axon is myelinated
REGENERATION OF NERVOUS TISSUE
neurons have very limited powers of regeneration
neurons lose the ability to divide at 6 months of age
any neuron destroyed is permanently lost
only certain types of damage to neuron cells can be repaired
PNS REGENERATION
PNS dendrites and axons may be repaired
1) if cell body remains intact
2) if Schwann cells remain active
CNS REGENERATION
CNS shows little repair of damage to neurons
injury to brain or spinal cord is usually permanent
1) axons of CNS are myelinated by oligodendrocytes and do not form neurolemmas
2) neuroglia of CNS inhibit axon regrowth
possibly the same mechanism that inhibits axonal growth during development once a target region has been reached
3) astrocytes invade area forming scar tissues which act as physical barriers to regeneration
NEURONAL REGROWTH
neuronal tumor cells
brains of some songbirds
nerve tissue appears and disappears every year
lack of mammalian CNS regeneration
1) inhibitory influences from neuroglia
2) absence of growth cues present during development
developmental cues are electrical and chemical in nature
use electrical or chemical stimulation to promote axon regrowth
EGF (1992) used to trigger mitosis
MYELIN DEVELOPMENT
amount of myelin increases from birth to maturity
myelin presence greatly increases the speed of nerve impulse conduction
infant response to stimuli are not as rapid or coordinated as those of older children or adults
myelination is still in progress
DISEASE OF MYELIN SHEATH
Tay-Sachs disease, diabetes mellitus and multiple sclerosis cause destruction of the myelin sheaths
Results in slowed action potential and impaired control of skeletal and smooth muscle
MULTIPLE SCLEROSIS (MS)
Progressive destruction of myelin sheath in CNS neurons
Chronic, disabling disease affection over 2.5 million people world wide
Myelin sheaths deteriorate to scleroses (hardened scars or plaques) in multiple regions
characteristics of the disease
1) progressive loss of muscle strength
2) strange sensations
3) double vision occurs periodically
4) "attacks" every year or two with periods of remission
implications of a viral cause which precipitates the activation of killer T-cells to destroy myelin producing oligodendrocytes
1993 FDA approved use of Betaseron (a form of interferon)
ENDONEURIUM
a connective tissue wrapping enveloping individual axons
PERINEURIUM
a connective tissue wrapping bundles or fascicles of axons
EPINEURIUM
a connective tissue sheath enveloping the nerve as a whole
These connective tissue sheaths help to give peripheral nerves a certain toughness and resistance to tearing
MYELINATION
most neuron axons are surrounded by a <u>myelin sheath</u>
protein lipid covering produced by neuroglia
1) electrically insulates axon
2) speeds up the transmission of nerve impulse through the axon

MEMBRANE POTENTIAL
plasma membrane exhibits membrane potential
resting potential
electrical voltage difference across the membrane
ACTION POTENTIAL
with stimulation resting potential can produce responses called action potentials
resting potential is like voltage stored in a battery
electric current produced by flow of electrons from negative to positive current
action potentials occur because plasma membrane contains ion channels that open or close in response to stimuli
ION CHANNELS
non-gated channels
    always open
gated channels
    open or close in response to stimuli
ION CHANNELS
plasma membrane has many more K+ non-gated channels than Na+ non-gated channels
thus membrane permeability to K+ is higher
GATED CHANNELS
gated channels are stimulated by:
    voltage
    chemicals
    mechanical pressure
    light
RESTING MEMBRANE POTENTIAL
occurs because of the build-up of negative charges in the cytosol (intracellular fluid)
equal build-up of positive charges in the extracellular fluid just outside the membrane
seperation of charges represents potential energy measured in millivolts
large +/- difference = large potential
potential exists only at membrane surfaces
resting membrane potential in the neurons is -70mV
cells with membrane potential are polarized
factors contributing to resting membrane potential
    1) unequal distribution of ions across the plasma membrane
        ECF - rich in Na^+ and Cl^-
        ICF - K^+ and PO_4^-, amino acids $^-$
    2) relative permeability of the cell membrane to Na+ and K+
        resting neuron permeability 50-100 times greater to K+ than to Na+
MEMBRANE PERMEABILITY
cell membrane has a low permeability for Na+ from outside of cell and Pr- inside cells
membrane has high permeability to K+ to move out of cell
tendency for K+ to move from inside the cell to outside down the concentration gradient
as K+ move out Na+ move down its concentration gradient into the cell
this has the effect of balancing electrical effect of K+ outflow
but Na+ inward flow is too slow to keep up with K+ outflow
net effect of K+ outflow is that the inner cell membrane surface becomes more negative
Na+/K+ PUMPS
both electrical and concentration gradients promote Na+ inflow
small inward Na+ leak is taken care of by Na+/K+ pumps
maintain resting membrane potential by pumping out Na+ as fast as it leaks in
Na+/K+ PUMPS
Na+/K+ pumps bring in K+
K+ redistributes immeadiately because it is permeable to the membrane
thus the critical job of the Na+/K+ pumps is to expel Na+
total effect is -70 mV resting membrane potential
ACTION POTENTIALS
"impulse"
occurs when depolarization is large enough at a trigger zone
depolariazation
membrane becomes less negative
    (more positive) than the resting level

IMPULSE
sequence of rapidly occuring events that decrease and reverse the membrane potential (depolarization) and then restore it to the resting state (repolarization)
two types of voltage gated ion channels open and close
- 1) first channels to open allow Na+ to rush into the cell causing depolarization
- 2) second channels open allowing K+ to flow out producing repolarization
  - lasts about 1 msec (1/1000 sec)

DEPOLARIZATION
stimulus causes inflow of Na+ bringing membrane potential from -70 mV to +30 mV
voltage gated Na+ channels open just long enough for about 20,000 Na+ ions to flow in
Na+ pumps bail the Na+ back out to the extracellular fluid

REPOLARIZATION
voltage gated K+ channels opened by depolarization
results in out flow of K+ ions
causing recovery of resting membrane potential
Na+ ion channels close
K+ channels open
membrane potential changes from +30 mV to 0 mV to -70 mV

REFRACTORY PERIOD
time where excitable cell cannot generate another action potential

PROPAGATION OF NERVE IMPULSES
1) continuous conduction
2) saltatory conduction

CONTINUOUS CONDUCTION
unmyelinated axons
muscle cells
as Na+ flows in
- 1) depolarization increases
- 2) opens voltage gated Na+ channels in adjacent patches of membrane

dominoes (self-propagation)
normally moves only one direction from where it arises
the membrane is refractory behind the leading edge of an action potential

LOCAL ANESTHETICS
novocaine / lidocaine used to block pain
block opening of voltage gated Na+ channels

SALTATORY CONDUCTION
Myelinated axons
Myelin sheath acts as an insulator
Blocks ionic currents across the membrane
Nodes of Ranvier
- Interrupt myelin sheath
- High density of voltage-gated Na+ channels
- Membrane depolarization can occur
- Currents carried by Na+ and K+ can flow across the plasma membrane
- Currents carried by ions through extracellular fluid around myelin sheath
- Current flows across membrane only at nodes
- Impulse appears to leap from node to node
- Current travels faster than in continuous conduction in fibers of equal diameter

SPEED OF IMPULSE
- 1) diameter of fibers
- 2) presence or absence of myelin sheath
- 3) temperature
  - ex. Pain reduced by localized cooling of nerve

FIBER DIAMETER
- **A fibers**
  - Largest diameter
  - All myelinated
  - Speed 12-130 m/sec (27-280 mph)
  - Touch, pressure, propriception, heat, cold, skeletal muscle motor nerves
  - Exist where quick ractions are critical

B fibers

myelinated
15 m/sec (32 mph)
sensory viscera nerves

C fibers (smallest)

unmyelinated
2m/sec (1-4 mph)
pain from viscera

IMPULSE SPEED

large diameter axons can transmit up to 2500 impulses/sec
small diameter axons can transmit only 250 impulses/sec
normal rate is 10-1000 impulses/sec

NEUROTRANSMITTERS

Neurotransmitters cause either

1) excitatory potentials
2) inhibitory potentials

EPSP

Excitatory Postsynaptic Potential
Membrane depolarizes
Result from opening of chemically gated cation channels
Allow Na+, K+, Ca++ to pass into the neuron
Na+ in flow is grater than Ca++ inflow or K+ outflow
Electrical and concentration gradients promote inflow

IPSP

Inhibitory Postsynaptic Potential
Membrane hyperpolarizes
Increases membrane potential by making inside more negative
Generation of nerve impulse more difficult
Often result from opening chemically gated Cl- or K+ channels
Inside becomes more negative by Cl- inflow or increased K+ outflow

REMOVAL OF NEUROTRANSMITTER

1) diffusion
2) enzymatic degradation
    ex. acetylcholine
3) cellular uptake

REMOVAL OF NEUROTRANSMITTER

active transport of neurotransmitter back into the neuron that released them (recycling)
cocaine produces intense pleasurable euphoria because it blocks transporters for the reuptake of dopamine
allows dopamine to linger in synthetic cleft
excessively stimulating certain brain regions

NEUROTRANSMITTERS

Excitatory and inhibitory neurotransmitters found in both PNS and CNS
Same neurotransmitter may be inhibitory in one location but excitatory in another
Type of receptors determines which response occurs
Neurons release up to 3 different neurotransmitters from their synaptic end bulbs

Ex. ACh

ACETYLCHOLINE

Excitatory at neuromuscular junction
Acts to open chemically gated ion channels
Inhibitory in parasympathetic fibers of Vagus nerve (cranial nerve X)
Innervates the heart
Slows the heart rate down

KNOWN NEUROTRANSMITTERS

60 known neurotransmitters
Parkinson's Disease, Alzheimer's Disease, depression, anxiety and schizophrenia are caused by neurotransmitter problems

1) acetylcholine
2) amino acids
3) biogenic amines
4) neuropeptides
5) gases

ACETYLCHOLINE
Released at NM junction
Released by axons of limbic system in brain
Destruction of these neurons is a hallmark of Alzheimer's Disease
AMINO ACIDS
Glutamate and aspartate are excitatory in the brain
GABA and glycine are inhibitory
GABA found primarily in the brain
Antianxiety drugs (valium) enhance the action of GABA
Glycine found primarily in the spinal cord
STRYCHNINE POISONING
Normally neurons release inhibitory glycine in spinal cord to motor neurons to prevent excessive muscular contraction
Strychnine binds and blocks glycine receptors
Result is massive tetanic contractions
BIOGENIC AMINES
Also called catecholamines
Actively transported back into the synaptic end bulbs after release
Reuptake by the neuron is required in order to recycle
NOREPINEPHRINE (NE) & EPINEPHRINE
May act as inhibitory or excitatory
Implicated in maintaining arousal, dreaming and mood regulation
DOPAMINE (DA)
Involved in emotional responses
Regulate gross automatic movements of skeletal muscles
Degeneration of neurons producing dopamine causes Parkinson's Disease
SEROTONIN (5-HT)
Induce sleep, sensory perception, temperature regulation and control of mood
Anti-depressant (Prozac) is a serotonin inhibitor of serotonin reuptake
    Thus more serotonin available in synaptic cleft
Allowing signals to pass from neuron to neuron more easily
NEUROPEPTIDES
May also act as hormones
- Angiotensin II - stimulates thirst
- Oxytocin - improves memory
- Antidiuretic hormone (ADH) - regulates water reabsorption
- Enkaphalins and endorphins - analgesic effects

ENKAPHALLINS AND ENDORPHINS
linked to improved memory, learning, feelings of pleasure and euphoria
200 X stronger than morphine
acupuncture may increase release of enkaphalins and endorphins (opioids)
GASES
Nitric oxide (NO)
- Released by endothelial cells lining blood vessels
- Causes relaxation and vasodilation
- Effect is to lower BP
- Allow for erection of penis in males

NITRIC OXIDE
Phagocytic cells produce NO to kill microbes and tumor cells
In large quantities NO is toxic
ALTERATION OF IMPULSES AND SYNAPSES
Alkalosis
acidosis
hypnotics
caffeine
etc.
ALKALOSIS
Increase in the pH above 7.45
Increases the excitability of neurons
Impulses arise inappropriately
Light headedness, numbness, tingling, nervousness, muscle spasms

ACIDOSIS
Decrease in pH below 7.35
Progressive depression of neuron activity
Produces apathy and muscle weakness
EXCESSIVE PRESSURE
Causes blockage of nerve impulse
"go to sleep"
HYPNOTICS, TRANQUILIZERS, ANESTHETICS
Increase the threshold for excitation
CAFFEINE, BENZEDRINE, NICOTINE
Reduce threshold for excitation
CHEMICAL SYNAPSE MODIFICATION
Clostridium botulinum bacteria in some canned foods produce a toxin
Toxin inhibits the release of ACh if ingested
Weakens muscle contractions
Small amounts are very poisonous
Strabismus, uncontrolled winking, stuttering are uncontrollable muscle contraction
Can be helped by injections of botulinum toxin
MYASTHENIA GRAVIS
Weakened muscle condition brought on by antibodies blocking acetylcholine receptors
Neostigmine and phystigmine
anticholinesterase agents that inactivate acetylcholinesterase
Results in slow removal of acetylcholine
Used to treat myasthenia gravis
DIISOPROPYL FLUOROPHOSPHATE
Powerful nerve gas
Anticholinesterase agent active in many insecticides
CURARE
Plant derivative
South American Indians poisoned arrows and darts
Blocks acetylcholine receptors causing muscular paralysis
May be used during surgery to relax muscles
Neostigmine is antidote for curare

END OF NERVE