Central Nervous System
Brain & Spinal Cord

Brain

one of largest organs in body:

men: 1,600 g (3.5 lbs)
women: 1,450g (3.2 lbs)

[size is proportional to body size not intelligence
→ Neanderthals had larger brains than us!!]

early thoughts on function of brain:
ancient Greeks weren't particularly impressed with the brain
where snot was generated
cooling device for blood

neurons divide only during prenatal development and a few months after birth

after that they increase in size, but not numbers

one of most metabolically active organs in body

comprises only 2% of total body weight it yet

→ gets 15% of blood

→consumes 20% of our oxygen need at rest (more when mentally active)

blood flow and O_2 increase to active brain areas

1-2 min interruption of blood flow may impair brain cells

>4 min w/o oxygen → permanent damage

besides O_2 must get continuous supply of glucose
very little in reserve

decrease in glucose:
dizziness
convulsions
unconsciousness

The Brain is Subdivided Into:

1. **Cerebral Hemispheres** (60% of brain mass)

   - "human" part: thought, creativity, communication

2. **Diencephalon** moods, memory, manages internal environment
   - epithalamus
   - thalamus
   - hypothalamus

3. **Cerebellum** – coordinating movement and balance

4. **Brain Stem** – oldest and smallest region, basic bodily functions = vegetative functions
   - midbrain
   - pons
   - medulla

Some General Terminology for CNS:

gray matter = thin myelin; mostly cell bodies dendrites & synapses

-outer layer of brain = **cortex**
-inner layer of spinal cord
-**nuclei**: small areas of gray matter deeper inside the brain

White matter = thick insulation; mostly axons

-inner layers of brain: **nerve tracts** = bundles of axons that interconnect various parts of the brain
-outer layer of spinal cord

Brain Stem

1. Medulla

lowest portion of brainstem

continuous with the spinal cord

all ascending and descending tracts from spinal cord and brain = **white matter**

most tracts cross over as they pass through the medulla

helps control several vital functions
→ contains important autonomic reflex centers

cardiac reflex center
rate and force of heartbeat

vasomotor control center
controls diameter of blood vessels
controls the distribution of blood to specific organs
controls blood pressure

respiratory center
regulates the rate and depth of breathing
polio especially affects this center in medulla
→ resp failure (iron lungs)

also contains many nonvital reflex centers (nuclei):
speech
swallowing
vomiting
coughing
sneezing
hiccuping

2. Pons

just above medulla

bridge connecting spinal cord with brain and parts of brain with each other

contains 2 centers that help to regulate breathing

→ **pneumotaxic center**
→ **apneustic center**

also contains nuclei that affect sleep and bladder control

3. Midbrain

in the form of 4 lobes above and behind pons
= **Corpora Quadrigemina**

upper 2 lobes = **Superior Colliculi**

control center for some visual reflexes:

a. **pupillary reflex**
b. reflex centers for coordinating eye movement with head and neck movement in response to visual stimuli

lower two lobes = **Inferior Colliculi**

control center for some auditory reflexes:

a. reflex centers for movements of head and trunk in response to auditory stimuli to locate sound

b. startle response to loud noises

also contains:

substantia nigra → suppresses unwanted muscle contractions

Parkinsons Disease
progressive loss of motor function
begins in 50's or 60's
can be hereditary
due to degeneration of dopamine releasing neurons in **substantia nigra** (inhibitory neurons)
leads to hyperactivity of **basal nuclei** and involuntary muscle contractions
results in shaking hands, facial muscles become rigid, range of motion decreases
develops smaller steps, slow shuffling gait with forward bent posture and a tendency to fall forward
speech becomes slurred, handwriting illegible

4. Reticular Formation (~Reticular Activation System)

diffuse system of interconnecting fibers extending through several areas of brain including brain stem

-comprises a large portion of entire brainstem
-extends into spinal cord and diencephalon
-interlacing of gray and white matter

Functions of RAS - both sensory and motor

1. Sleep and consciousness

maintains consciousness and awakens from sleep → alarm clock

barbiturates depress RAS, decrease alertness & produce sleep

amphetamines stimulate RAS producing wakefulness

general anesthetics may produce unconsciousness by depressing RAS

falling asleep may be caused by specific neurotransmitters that inhibit RAS

2. helps control muscle tone, balance and posture during body movements

3. filters flood of sensory input (=habituation)

highlights unusual signals; disregards rest (99%)

LSD interferes → get flood of sensory stimuli

Diencephalon

1. Epithalamus

includes roof of 3rd ventricle

mainly pineal gland

2. Thalamus:

4/5ths of diencephalon

1.2" long

forms lateral walls of 3rd ventricle

and intermediate mass

mainly a sensory relay center

→ *"Rome of the Nervous System"*
or
"gateway to cerebral cortex"

→ main **relay station for sensory impulses** that reach cerebral cortex from spinal cord, brain stem and cerebellum

eg. taste, touch, heat, cold, pain, some smell

the only sensory signals that can reach the cortex without going through the thalamus are for sense of smell

3. Hypothalamus

part of the brain most involved in regulating internal environment

no blood brain barrier

forms floor and part of lateral walls of 3rd ventricle

a. link between "mind" and "body"

controls and integrates activities of autonomic NS

means by which emotions express themselves by altering body functions

→ ?role in psychosomatic illnesses

b. relays reflexes related to smell

c. manufactures and transports releasing hormones that control the "Master Gland"

→ anterior pituitary

e. regulates body temperature

has receptors that monitor blood temperature

f. regulates food and water intake

has receptors that monitor osmotic pressure
→ thirst center

other receptors monitor some hormone concentrations in blood

4. Limbic System

diencephalon is a main part of a diffuse group of structures called the **Limbic System**

includes thalamus, hypothalamus, hippocampus, midbrain, amygdala (cerebrum), mammalary body (relay center from limbic system to thalamus), fornix (connects hippocampus to mammalary body of hypothalamus)

= the emotional brain

limbic system perception & output is geared mainly toward the **experience and expression of emotions**

eg. pain, anger, fear, pleasure

continuous back & forth communication between limbic system and frontal lobes of cerebrum

→ much of the richness of your emotional life depends on these interactions

outward expression of these emotions requires participation of the hypothalamus

all sensory impulses are shunted through the limbic system

smell is directly wired to limbic system

produces a crude appreciation of some sensations; eg. pleasure, anger, pain

but can't distinguish their location or intensity

eg. contains **pleasure center**

-rats pressing bar for stimulation of pleasure center
-ignore sleep, food, water, sexual partners
-continue until exhausted (50-100x's/min)
-willing to cross electrified grid to seek reward
[420 μamps vs 60-180 μamps for food]

in humans stimulates erotic feelings

opioids and endorphins are concentrated in limbic pathways

→is site of action of many addictive drugs

<u>Cerebellum</u>

2nd largest part of brain

just below and posterior to cerebrum

only other part of brain that is highly folded

consists of 2 hemispheres

grey matter outside

white matter inside

= **arbor vitae** (tree of life)

Functions of Cerebellum:

helps to coordinate voluntary muscles:

but does not send impulses directly to muscles

1. acts with cerebrum to **coordinate different groups of muscles**

smooths and coordinates complex sequences of muscular activity needed for body movements

2. controls skeletal muscles to **maintain balance**

receives input from proprioceptors in muscles, tendons and joints and equilibrium receptors and eyes

→ compares intended movement with actual movement

3. **learning and storing motor skills**

eg. playing musical instrument, riding a bike, typing, etc

4. recent research indicates that the cerebellum also has roles in awareness, emotion and judging the passage of time

diseases of cerebellum produce **Ataxia**

eg. tremors
speech problems
difficulty with equilibrium

NOT paralysis

<u>Cerebral Hemispheres</u>

largest portion of brain (~60% of brain mass)

two hemispheres joined by tracts = **corpus callosum**

heavily convoluted: **gyri** and **sulci**

folding allows greater area of cortex in smaller space (area = 2,500 cm^2 = area of 4.5 textbook pages or 1 keg of beer)

also has larger grooves (= **fissures**) that divide each hemisphere into 4 main regions named after bones they lie under:

1. **frontal**
2. **parietal**
3. **occipital**
4. **temporal**

each hemisphere:

a. outer **gray matter** = cerebral **cortex** (2-4mm)

b. inner **white matter** = **tracts**

→ bundles of myelinated axons

c. **nuclei** = islands of gray matter in interior of brain

→ cell bodies and sometimes dendrites

eg. basal nuclei (=basal ganglia)
clusters of gray matter around thalamus (5)
help direct movements
overactivity due to lack of dopamine produces Parkinson's disease

hemispheres connected by nerve tracts in **corpus callosum**

Function of Cerebral Cortex:

neurons of cortex are arranged into a highly organized, radial array of 6 cellular layers (=neocortex)

→ differ in
composition
functional properties
sets of connections

cortex has been systematically subdivided into >40 functionally distinct areas

cortex is responsible for our most "human" traits

conscious mind
abstract thought
memory
awareness

A. on simplest functional level, the cerebral cortex contains:

a. motor areas
that control voluntary motor functions

b. sensory areas
provide conscious awareness of sensations

c. association areas
integrate wide variety of information from several different areas of brain

each hemisphere is mainly concerned with sensory and motor functions of the opposite side of the body

eg. left hemisphere controls right hand

B. Lateralization of Hemispheres

on top of this basic functions is "**lateralization**":

a specialization of some cortical functions into each hemisphere

a division of labor

→ each hemisphere takes on complementary functions

Left Hemisphere:

1. does all the talking

→ repository of language

→ processes many aspects of language: syntax, semantics, etc

→ also analytical skills, math, logic

Right Hemisphere:

1. mainly concerned with **visuospatial tasks**

2. nonverbal communication: interprets more subtle aspects of language - metaphor, allegory, ambiguity

3. also concerned with emotions, intuition

4. global holistic aspects of sensory processing

eg. does reality checks of new information

eg. holistic aspects of vision

→ "reading" facial expressions

→ recognize faces

there appears to be a gender difference in brain lateralization

males process spatial tasks in right hemisphere by 6 yrs of age
females spatial function is equally developed in both hemispheres until age of 13

→ damage to rt hemisphere in childhood impairs language devel in males more than females

<u>Hemispheric Dominance:</u>

lateralization as described is true for 97% of all people

for ~90% of these people
→ traits characteristic of the left hemisphere are dominant more verbal, analytical

all are right handed

for 7% of these people
→ traits characteristic of right hemisphere are dominant
visuospatial tasks
these are left handed
more likely to be males

for 3% of population functions are shared = bilateral (no dominance)

lateralization is reversed or reduced in bilateral folks
often ambidextrous
sometimes leads to confusion and dyslexia

C. Lobes of the cerebrum

fissures divide each hemisphere into 4 regions, each with a specific set of functions:

1. **frontal**
   personality
   control of voluntary movement
2. **parietal**
   touch, stretch
   perception of somatic sensations
3. **occipital**
   processing of vision
4. **temporal**
   processing of sound and speech
   awareness of equilibrium

1. Frontal (& prefrontal)

Prefrontal:
elaboration of thought
intelligence
motivation
personality
abstract ideas
judgement
planning
"civilizing behaviors"

damage:
wide mood swings
loss of attentiveness
become oblivious to social constraints
careless about personal appearances

prefrontal lobotomy
reduced anxiety
but lost initiative
had mood swings

Frontal

motor processing areas:

a. **Motor Cortex**

directs conscious individual muscle contractions

large body zones → homunculus

within each zone: neurons that control specific movements are scattered as combinations of muscles are arranged in useful ways

damage causes paralysis

c. Olfactory Cortex

small area just above orbits
perception of odors, smells

2. Parietal Lobe

sensory processing areas

a. Sensory Cortex

receives information from skin sensors

when stimulated patient reports "feeling" in some part of body

muscle, tendon and joint sensations, and touch provides feedback to motor cortex

spatial discrimination

motor and sensory cortex, like other areas are malleable

eg. learning Braille
the area representing touch in the finger used in somatosensory cortex expands into areas previously devoted to neighboring fingers

c. Gustatory Cortex

conscious awareness of taste stimuli

3. Occipital Lobe

visual processing areas

a. Visual Cortex

image is 1st mapped here
receives info from retinas of eyes
analyzes image in terms of its elementary features
orientation
color
texture
depth
presence of movement

4. Temporal Lobe

a. Auditory Cortex & Association Area

interprets sounds: pitch, rhythm, loudness

b. Vestibular (equilibrium) Cortex

awareness of balance

Higher Brain Functions

Integration → interaction of several areas or processes occurring at the same time

most not hard wired, circuits constantly forming and reforming

these functions are much more complex than simple reflex arcs

→ often involve learning

just beginning to understand them and some of the programming involved

Examples:

Sleep/Wake Cycles
Language and Speech
Consciousness = Self Awareness
Emotions and Behavior
Memory and Learning
Abstract Thought
Intelligence

Language and Speech

language is closely associated with distinctly human brain functions

seems to be an innate process

→world's languages are all governed by the same universal grammar

→ all infants are born with the ability to learn all human languages

however this ability diminishes with age

integrated with memory and consciousness

it can't be all under conscious control since it happens so quickly

also, cant be all reflex

Language involves up to 6 areas in cerebral cortex:

1. **Broca's speech area** (frontal lobe)
   motor aspects of speech and language
   active when speaking
   or when moving tongue and hands
   muscular coordination for speech

   damage: aphasia
   slow and poorly articulated speech
   loose ability to speak fluently and grammatically and to express ideas in writing
   comprehension not affected

2. **Wernicke's Area** (temporal lobe)

comprehension of written and spoken word
active in children while reading
and in adults reading unfamiliar words
speech integration
impulses from visual and auditory assoc
connects to Broca's area

damage: aphasia
rapid, fluid speech
no information content– "word salad"
no comprehension of spoken or written language

Wernicke's area is reduced in size in dyslexics

3. neurons in Left frontal and midfrontal cortex
   responsible for semantics
   word associations
   symbolic processing

4. Left Frontal Cortex
   essential for enunciating verbs

5. Left temporal cortex
   "whips out" nouns

6. Occipital Lobe
   color concepts and associations

Consciousness

What exactly is consciousness?

little is actually known but some generalizations:

1. involves simultaneous activity of large areas of cerebral cortex

→ localized damage of specific region does not destroy consciousness but does alter it

2. is superimposed onto other types of neural activity

3. is totally interconnected

Awareness

one of the simplest forms of consciousness is **awareness (=perception)**:
of surroundings
of sensations
of relationships to those stimuli

consciousness is often defined as "self" awareness

what is **self**? or self identity

→ requires interactions of numerous specific brain areas

one of most important senses that gives us information about our surroundings and interactions with it is **vision**

visual stimuli that reach brain are first mapped into visual cortex
visual imprint of retinal image:

from there it goes to ~30 areas in cortex for higher level processing

information from primary visual cortex is then relayed through 2 pathways:

→ **How Pathway** to parietal lobe
to discern spatial layout of outside world

allows you to reach out for objects, know where you are

→ **What Pathway** to temporal lobe
to recognize and name individual objects and respond to them appropriately with emotion

(?the man who mistook his wife for a hat?)

eg Neglect patients

esp if Rt parietal lobe is damaged

The right hemisphere has broad "sphere of interest" encompasses both left and right visual fields

If right is damaged

→ temporary **neglect** of left side of body
doesn't pay attention to left side of space or anything in it

eg. draw 1/2 of a picture
(left doesn't exist)
eg. eat from only rt side of plate
-one patient "knew something wasn't right"
-rolled wheelchair in huge circle (clockwise) till

she could "see" the left side of the plate in her right field of view
-never occurred to her that she could just turn left
-left didn't exist

→also show "mirror confusion"
try to reach through mirror for objects

→ also may have difficulty reading maps or finding their way around the house

is not blindness but indifference

receives sensation, lacks correct perception of what they indicate

most, not all, such patients recover in a few weeks
yet most benefit from exercising left arm is during this time when "left" doesn't exist – why exercise?

The left hemisphere "sphere of interest" is only the right side of the body and the world

→ If left is damaged
right can compensate

visual awareness (perception) is not just the image imprinted on retina

it's a **neural image** formed in cortex

that neural image is not a completely accurate

representation of what is going on in the world

brain can "fill in" (eg. blindspot) by extrapolation
eg. blind spot is filled in
eg. Necker cube
eg. faces/vase

some have larger areas of "blindness" due to damage and fill in with hallucinations:

→ no reaffirming information to "squash" hallucinations

→ sometimes patient "knows" they are hallucinating – but can't get rid of them

eg. monkeys in lab
eg. cartoon characters

but, even your own body is a phantom

your brain temporarily constructs it for your convenience

it can be profoundly modified with simple tricks

eg. how deeply do denial patients believe they are not paralyzed
cold water in ear corrects delusions and denial about paralysis, etc

ck? dummy hand in front of 2'x2' wall
have friend stroke identical location on dummy and your hand

Disorders:

certain variations in levels of consciousness are normal:
awake & alert
relaxed & nonattentive
sleep

altered states of consciousness also occur
anesthesia
coma
induced by injury or disease
no vocalizations, no spontaneous eye movements
brainstem reflexes intact
"trip"
eg LSD
meditation
eg yoga
confusion
alteration in perception of stimuli
disorientation to time first, then to place, eventually to person
shortened attention span
lethargy, stupor, obtundation

locked-in state
motor nerves cease functioning; the body is completely paralyzed while the mind continues to function normally; patient may appear to be clinically dead

synesthesia

all of our senses contribute to consciousness
(not just vision)

hallucinatory welding of senses:
2 or more sensations are comingled

sensory impulses not sent to appropriate sensory areas of cortex

eg. a musical note may taste like pickles
eg. a guitar chord may be felt as a brushing sensation on ankle
eg. the taste of chicken may feel "round"
eg. a boyfriends kiss was seen as "orange sherbert foam"
eg. see brilliant blue after eating salty pretzel
eg. specific letters or number → associated with specific colors
eg. feel pain in colors

these perceptions are consistent over time for one person

but not necessarily the same for other synesthetes

1 person in 2000 is a synesthete;
but may be even more common 1 in 300

more common in women: 6 women to 1 male

seems to run in families: genetic component

Is there a consciousness "center" in the brain?

does consciousness arise from specialized brain circuits?
→ brain lesions that produce the most profound disturbances in consciousness are due to "temporal lobe seizures"

→ epileptic seizures sometimes produce profound experiences

temporal lobe is associated with:
auditory hallucinations
out of body experience
"religious" experiences
→ feelings of absolute omnipotence
→ feelings of omniscience
→ insights into "cosmic truths"

sense of truth and enlightenment derive from limbic structures rather than "thinking" part of the brain

<u>Intelligence</u>

what is anatomical/physiological basis for intelligence?
brain mass
neurons in brain?, in cerebrum?
synapses?

where is it centered?
→is our intelligence part of our cortex?

may be the ability to juggle lots of possibilities

working memory may play important role

<u>What we know:</u>

a. intelligence may have more to do with when and how the brain grows than with its overall size

→the brain regresses as it matures

eg. 3-11 yr old has 2x's energy/gm as 11-14 yr old

eg. the cerebral cortex thickens in childhood, peaks and then thins again in adolescence

→2x's # synapses in certain areas of child's brain vs adolescent brain

b. angular gyri in cerebral hemispheres is important

eg. we know damage to angular gyrus in left hemisphere can leave "intelligent" people unable to do simple subtraction (eg. 100-7)

eg. we know damage to angular gyrus in right hemisphere leads to disruption of artistic skills

c. specific circuits are used for specific functions

Savants are mentally retarded yet some can:
→ replay any music when heard once
→ state exact time of day with no clock in sight
→ exact counts of numerous objects
eg "rainman"
→ can tell you in span of 40,000 years, the day of the week any date you choose fell on

*Jeremy can stand at the side of the railroad tracks and give you the cumulative total of the serial numbers on the boxcars

*George can tell you all the years in which your birthday fell on a Thursday

* George can also tell you within a span of 40,000 years backward or foreward, the day of the week on which any date you choose fell or will fall

*Leslie, upon hearing Tchaikovskys Piano Concerto No 1 on the piano for the first time can play it back flawlessly and without hesitation

*Ellen constructs complicated chords to accompany music of any type she hears on radio or TV. She can sing back the entire soundtrack of the musical Evita after one hearing while transposing orchestra and chorus to the piano

*Kenneth can give the population of every city and town in the US with a population over 5,000; the names, number of rooms and locations of 2,000 leading hotels in the US; the distance from each city and town to the largest city in its state; and the dates and essential facts of over 2,000 inventions

*Jedediah can answer the question: "in a body whose three sides are 23,145,789 yards, 5,642,732 yards and 54, 965 yds, how many cubicle $1/8^{th}$'s of an inch exist" after 5 hours of computation he has the correct 28 digit figure and asks "do you want it backwards or forewards"

*David can be given the number of the bus and time of day, and tell you on what corner you are standing in milwaukee

most savants are not truly "creative"

rote, not interpretive

d. there is lots of redundancy and plasticity in the brain in terms of intelligence

John Lorber asks:
"*Is your brain really necessary?*"

most of brains higher functions are mediated by cortex
→we view the cerebrum as what makes us

human

he studies **hydrocephalic** patients
→ extremely large cavities in brain, brain mass, including cerebral cortex is greatly reduced

many hydrocephalics suffer intellectual and physical retardation

but of ~60 whose brain scans showed water cavities filled 95% of skull

→ ~ half had IQ's > 100 (normal IQ=90-110)

eg. Hydrocephalic boy = honor student
had <20% of normal cerebral cortex
(his 1 mm (1/32"); normal = 4.5 cm (1.75"))

normal IQ = 90-110; his = 126

Spinal Cord

located in the spinal canal of the vertebral column

17 – 18 inches long

extends from foramen magnum to lower border of 1st lumbar vertebrae

subdivided into **cervical**, **thoracic**, **lumbar**, **sacral** regions

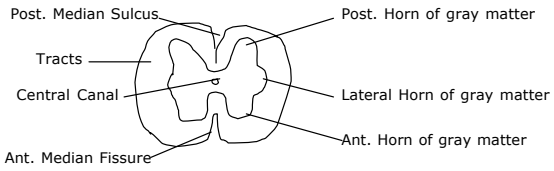
spinal cord terminates in a bundle of nerves
= **cauda equina**

associated with cord in spinal canal are:
meninges
adipose cushion
CSF
blood vessels

space between vertebrae and dura mater
= **epidural space**

is occupied by blood vessels, adipose tissue and loose connective tissue

Cross Section of Spinal Cord:



white matter: myelinated, divided into columns and tracts; "highways"

gray matter: unmyelinated, cell bodies & dendrites, synapses

Nerve Tracts

numerous tracts can be identified in the spinal cord

spinal cord tracts serve as 2-way conduction paths between peripheral nerves and brain

each tract is composed of bundles of axons

ascending tracts & descending tracts

eg. spinothalamic tract
all axons originate from cell bodies in spinal cord and terminate in thalamus of brain
all are sensory (ascending)

Protection of CNS

both brain and spinal cord are heavily protected:

1. **bone**: skull and vertebral column
2. **adipose cushion** around spinal cord
3. **meninges**: tough flexible covering
4. **liquid cushion**: cerebrospinal fluid

Meninges

composed of 3 layers:

1. dura mater

strong fibrous connective tissue

outer layer in skull is periosteum of cranial bones

2. arachnoid layer

delicate cobwebby layer

subdural space = between dura mater and arachnoid membrane

subarachnoid space = between arachnoid layer and pia mater

3. pia mater

transparent

adheres to outer surface of brain and cord

contains blood vessels

3 extensions of the meninges form partitions between various parts of the brain:

falx cerebri
largest partition
between cerebral hemispheres

falx cerebelli
separates cerebellar hemispheres
not in sheep brain

tentorium cerebelli
separates cerebrum from cerebellum

meninges continues around spinal cord and extends beyond the end of the spinal cord

→safer site for lumbar puncture to get CSF

Meningitis = inflammation of arachnoid, pia and CSF
usually bacterial or viral; may lead to encephalitis

Encephalitis = inflammation of brain tissue itself

Cerebro Spinal Fluid

as further protection against damage the brain and spinal cord have a cushion of fluid around and within

→ brain actually "floats" in CSF (~140 ml of CSF)

CSF provides buoyancy and protection to delicate brain tissues also produces chemical stability

CSF mainly in:

a. brain **ventricles** and **ducts**

b. **central canal** of spinal cord

c. in **subarachnoid space** of the **meninges**

→space between arachnoid layer and pia mater

Ventricles

ventricles are fluid filled cavities inside brain:

1st & 2nd in side cerebral hemispheres = lateral ventricles

3rd small slit at base of brain inside diencephalon (thalamus)

4th diamond shaped expansion of central spinal canal in brainstem

capillary beds in pia mater of meninges extend into the 4 ventricles of the brain where they form **choroid plexi**

surrounded by **astrocytes** (blood brain barrier)

each **choroid plexus** secretes CSF into ventricles

produces ~500ml of CSF/day

→ only 100-160ml at a time in circulation

isolated by "**Blood Brain Barrier**"

capillaries are much less leaky than normal capillaries
→ tight junctions
→ astrocytes help regulate flow into CSF

some substances easily, rapidly passed:
glucose, O_2, CO_2, alcohol, caffein, nicotine, heroin, anesthetics

others cross more slowly; creatinine, urea, most ions (Na^+, K^+, Cl^-)

larger molecules cannot cross at all; proteins, antibodies

→difficulty getting drugs to brain tissue

→any trauma to head may damage BBB

Circulation of CSF

Choroid plexus in each ventricle

fluid moves from lateral ventricles through **duct** to 3rd ventricle

another **duct** moves fluid to 4th ventricle

fluid moves to **central canal** of spinal cord

fluid moves out to **subarachnoid space** around cord and brain

reabsorbed from subarachnoid space into **arachnoid granulations**

if circulation is blocked by tumor or other means during fetal development may cause **hydrocephalus**

→ fluid is still produced but can't circulate and be reabsorbed

Aging Central Nervous System

reaches peak development ~30

by age 75 average brain weighs slightly half its 30 yr weight

- gyri are narrower
- sulci are wider
- cortex is thinner
- more space between brain and meninges

neurons show signs of slower metabolism, accumulate neurofibrillary tangles and lipofuscin pigment

less efficient signal conduction and transmission

myelin sheath degenerates

fewer synapses

less NT produced, fewer receptor proteins

language skills and long term memory hold up better than motor coordination, intellectual function and short term memory

Disorders of the
Central Nervous System

migraine headaches:
- often debilitating and excruciating headaches
- 10-12% of US →28M in US suffer;
- ~70% are women
- 92 M workdays lost/yr; $11 B/yr (AAS 97)
- 2 kinds:

Classic (with aura)
- some or all of symptoms:
  - seeing zigzagging lines
  - tingling or numbness in face, arm, leg
  - seeing blind spots and tunnel vision

Common (without aura)
- pain on one or both sides of head
- nausea
  - sometimes vomiting
  - sensitivity to light, smell or noise
  - throbbing, intense pain

may be due to:
- a. fluctuations in levels of serotonin
  - imitrex increases serotonin levels to stop headache
- b. excessive levels of dopamine
- c. may be a genetic component

Tourette's Syndrome
- recurrent involuntary muscle contractions = tics
  - eg. eyeblinking, nose twitching, facial grimacing, head shaking, shoulder shrugging
- usually begins in childhood between ages of 2 – 15
- worldwide, all races; males more than females
- may affect 1 in 2000, worldwide; US ~100,000 affected
- may be due to chemical abnormality in basal ganglia

- one type of tourette's in inherited

Alzheimers Disease
- affect 11% in us over 65; 47% by 85
- ~half of all nursing home admissions
- leading cause of death among elderly
- AD may begin before 50 with very mild, undiagnosed symptoms
- one of 1st symptoms is memory loss, esp of recent events
- progresses with reduced attention span, disorientation, moody, confused, paranoid, combative or hallucinatory
- may lose ability to read, write, talk, walk, and eat
- death usually from pneumonia or other complications of confinement and immobility

Parkinsons Disease
- progressive loss of motor function
- begins in 50's or 60's
- can be hereditary
- due to degeneration of dopamine releasing neurons in substantia nigra (inhibitory neurons)
- leads to hyperactivity of basal nuclei and involuntary muscle contractions
- results in shaking hands, facial muscles become rigid, range of motion decreases
- develops smaller steps, slow shuffling gait with forward bent posture and a tendency to fall forward
- speech becomes slurred, handwriting illegible