Anatomy of Brain and Cranial Nerves

I. Orofacial Region

- respiration, speech, swallowing, eye movements, afferent information and communication of emotion
- Sensory: **Trigeminal Nerve** (CN V) – specific portions of faced innervated by specific portions of nerve; not analogous to dermatomes because no overlap between segments
- *Ophthalmic* (V1) – final segment = supraorbital nerve
- *Maxillary* (V2) – final segment = infraorbital nerve
- *Mandibular* (V3) – final segment = mental nerve

Clinical Correlation:
Trigeminal neuralgia – shooting pain along branch of trigeminal nerve, caused by lack of blood to ganglia – mediated by primary neurons
Area of cortex map for face = size of map for rest of body – highly sensitive
Trigeminal nerve refers pain from one branch to another

- Motor: **Facial Nerve** (CN VII) – passes through parotid gland in one plane
- *Temporal*
- *Zygomatic*
- *Buccal*
- *Mandibular*
- *Cervical*

Clinical Correlation:
Bell's Palsy – problem with facial nerve in parotid gland
- may lead to drooling (orbicularis oris), problems with chewing or swallowing (buccinator) or tearing/opening and closing eye (orbicularis oculis)

Cranial Nerves

Nerve	Afferent?	Efferent?	Taste?	Parasympathetic?
III Oculomotor	No	Yes	No	Yes
IV Trochlear – innervates single muscle	No	Yes	No	No
V **Trigeminal**:[1]				
V1 Ophthalmic	Yes	No	No	No
V2 Maxillary	Yes	No	No	No
V3 Mandibular	Yes	Yes	No	No
VI Abducens – innervates single muscle	No	Yes	No	No
VII **Facial**	Yes	Yes	Yes	Yes
IX Glossopharyngeal	Yes	Yes	Yes	Yes
X Vagus	Yes	Yes	Yes	Yes
XI Spinal Accessory	No	Yes	No	No
XII Hypoglossal	No	Yes	No	No

[Not considered: I, II and VIII]

- Yes to afferent: three neuron pathway
- Yes to efferent: two neuron pathway

[1] Note: the sensory root of the trigeminal nerve is significantly larger than the motor root is.

- Yes to parasympathetic: preganglionic and postganglionic set of neurons
- III, IV, VI, XI and XII – innervate muscles derived from somites (eye and tongue)
- V, VII, IX and X – innervate muscles derived from brachial arches

Muscles of Facial Expression

- platysma
- orbicularis oris
- orbicularis oculi
- palebral
- orbital
- (lacrimal)
- frontalis/(corregador)
- buccinator
- masseter

Arterial supply – external carotid; branch = facial artery
Venous drainage – facial vein to angular vein to ophthalmic vein; connected to cavernous sinus

- infection on lips or nose may tract into brain via the cavernous sinus, leading to meningitis

Skull

- little deep fascia in face means that any fracture causes grotesque swelling
- fractures most likely occur across nose or mandible (bottom, neck or condylar portion – usually paired fracture)
- facial skull is more fragile, has more bones and therefore more sutures than neural skull
- Le Fort Facial Fractures

II. Anatomy of Neural Skull

- Cranium: encloses entire brain and protects it from trauma
- No room for compression: expansion inside brain (usually circulatory origin) has serious consequences

Scalp: compressible, moveable to dissipate the force of a blow

- **S**kin
- **C**onnective Tissue:
  Superficial temporal arteries and veins
  - arteries are branches of *external carotid artery*
  - massive collateral circulation; no end arteries – bleeds from both ends when cut
  - veins are part of network of venous channels – flow of blood is depend on posture
  - interconnect to sinuses inside brain; infection can tract inside, leading to meningitis
- **A**poneurosis
- **L**oose connective tissue
  - possible extravasation of fluid
  - possible pathway of infection
- **P**eriosteum of skull

Skull

- thin where skull interdigitates with face and in temporal region
- vibrates when hit
- inner and outer lamina (a.k.a. tables)
- separated by spongy bone (diploe) – contain *diploic veins* connected to internal and external veins

Meninges

1. Dura Mater – 2 layers

- outer = periosteum of inner table; tightly adherent to skull bone
- **Epidural space** = potential space between outer dura and inner skull
- at foramen magnum, outer layer continues with skull
- inner = dura mater proper; at foramen magnum, continues as dura mater of spinal cord
- Layers are separated in three places**:**
    1) Meningeal blood vessels
        - pass through foramen spinosum
        - sit in grooves in cranial vault; may rupture with skull fracture
    2) Superior Sagittal Sinus
    3) Dural Septum – folds of inner layer e.g. falx cerebris

2. Archnoid

- loose attachment to dura though follows its contours
- *arachnoid villus*: where CSF exits; projections into dural sinus from arachnoid layer - one way valve: CSF flows because blood vessels pulsate with heartbeat
- subarachnoid layer: contains CSF and the arteries and veins that supply the brain

3. Pia Mater

- follows contour of brain
- contains capillary networks to nourish brain tissue; follows blood vessels down
- Blood-brain barrier: no neurons actually touch blood – difficult to get drugs into brain
- *Choroid Plexus*: invagination of pia mater that produces CSF

Clinical Correlations:

1. **Epidural Hematoma**

- large mass of arterial blood between inner layer of skull and outer dura
- CT scan: lenticular configuration; blood does not dissociate dura over extensive area
- Rapidly fatal:
- Compresses brain and pushes it onto brain stem
- CN III: innervates muscles of eye – problems with eye movement and eyelid = eye droop
- Parasympathetic to sphincter of eye: pupils dilate
- Compresses cerebral artery
- Interferes with descending tracts

2. **Subdural Hematoma**

- where vein in subdural space crosses into venous sinus
- venous blood; may become chronic with increased blood pressure

3. **Subarachnoid Space**

- swellings in venous system
- aneurysms in circle of Willis: blood in CSF
- often result of contusions

Brain held in place by infoldings of dura mater
- **falx cerebri, falx cerebelli and tentorium**
- also attached to spinal cord, attached to coccyx by filum terminale

Six places where dura is very adherent to skull:
- crista galli of ethymoid bone
- clinoid process of sphenoid bone x 2
- petrous ridge of temporal bone x 2
- internal occipital protuberance

Venous System
- *superior sagittal sinus* – drains all superior surfaces of cerebral hemisphere
- *confluens* of sinuses to right transverse sinus to *right sigmoid sinus* to right jugular vein
- *inferior sagittal sinus*- drains all deeper veins from deeper surfaces of brain
- joins with *great vein of Galen* to form *straight sinus* to
- *confluens* of sinuses to left transverse sinus to *left sigmoid sinus* to left jugular vein

- *cavernous sinus* – in sella turcicia around pituitary gland
- internal carotid artery passes through the middle of the cavenous sinus
- also contains CN III, IV, IV and V1 (ophthalmic n.)
- rupture of internal carotid artery: pulsating exophthalmus – eye throbbing, pushing forward because of engorged veins
- *emissary veins* – lead directly through skull into sinus

Cranial Nerves: Neuronal Components and Regulation of Afferent and Efferent Pathways

Brain
- sagittal fissure, lateral cleft and central sulcus – at midline with gyrus on either side
- *Frontal Lobe*
- Broca's area: muscles of speech
- Formulation of ideas and socialization
- **Precentral gyrus**: motor homunculus
- tragal line = interface between spinal and cranial nerves

~ eyeball/eyelid: CN III, IV and VI
~ face, lips: CN VII
~ tongue: CN XII

- *Parietal Lobe*
- **postcentral gyrus**: sensory homunculus
- trigeminal nerve
- *Temporal Lobe*
- Heschl's gyrus – comprehension of speech
- *Insular Lobe* - taste
- *Corpus Callosum* – large connection between right and left hemispheres

Neuronal Components of Cerebral Cortex

- 99% of output of cortex goes to cortex
- most of brain involved in cognition, not motor
- input = thalamus – processes sensory info

Basal Ganglia – regulate motor movements

- caudate nucleus
- putamen
- globus pallidus
- "inhibitory surround:" inhibit activation that you don't want and let good ones through
- input = substantia nigra

Clinical Correlation:

- damage to substantia nigra leads to Parkinson's – tremors and inability to initiate movement; L-Dopa was early treatment

Foramina of Neurocranium

Foramen	Nerve	Artery	Vein
Cribiform plate	Olfactory nerve bundles (dendrites)		
Optic canal	Optic nerve (CN II)	Ophthalmic artery	
Superior Orbital Fissure	Oculomotor nerve (CN III) Trochlear nerve (IV) Ophthalmic nerve (V1) Abducens nerve (VI)		Superior Ophthalmic vein
Foramen rotundum[2]	Maxillary nerve (V2)		
Foramen ovale	Mandibular nerve (V3)	Accessory Meningeal Artery	
Foramen spinosum	Meningeal branch of mandibular nerve	Middle Meningeal artery	Middle Meningeal vein
Carotid canal	Internal carotid nerve plexus	Internal carotid artery	
Internal Acoustic Meatus	Facial nerve (VII) Vestibulocochlear nerve (VIII)	Labyrinthine artery	
Jugular foramen	Glossopharyngeal nerve (IX) Vagus nerve (X) Accessory Nerve (XI)	Posterior Meningeal Artery	Sigmoid Sinus
Hypoglossal canal	Hypoglossal nerve (XII)		

III. Cranial Nerves: Activation of Efferent Pathways

[2] Pneumonic for branches of trigeminal n.: **S**tanding **R**oom **O**nly
– V1 goes out **s**uperior orbital fissure; V2 goes out foramen **r**otundum**;** V3 goes out foramen **o**vale

- motor homunculus
- wide band associated with vocalization, mastication and swallowing
- represent collectives of neurons activated together = Reflex activation

- **Brainstem**

1. *Medulla Oblongata*
- extends from spinal cord to pons
- involved in reflex activity activated by autonomic nerves]
- CN IX, X, XI and XII

2. Pons and Cerebellum
- metrics of movement

3. *Midbrain*
- nerves that move muscles of the eye

3. *Diencephalon*
- hypothalamus
- pituitary gland
- **thalamus**:

~ midline mass, medial and posterior to basal ganglia (control over motor function)
~ processes all afferent information except olfaction, then projects that info onto the cortex

- **Ventroposterolateral Nucleus (VPL)**: all info from the spinal cord; concerns the body
- **Ventroposteromedial Nucleus (VPM)**: all info from the cranial nerves; concerns the face

- both project onto correct portions of sensory homunculus

- **Lateral Geniculate Nucleus**: concerned with vision; projects onto occipital lobe
- **Medial Geniculate Nucleus**: concerned with hearing; projects onto Heschl's gyrus/auditory cortex

<u>Pathways of Cranial Nerve Efferents</u>

- **Internal Capsule** – tract that contains axons passing between basal ganglia and thalamus
- becomes **corona radiate** as soon as axons leave confines of basal ganglia

How does system work?

- motor inputs enter basal ganglia from the cerebral cortex
- basal ganglia sends input to thalamus, the sensory input center

- basal ganglia serves as a filter for motor information and shuts down other circuits
- in order to survive, must check awareness of environment before initiating movement
- Clinical correlation:If the basal ganglia is damaged, symptoms include spontaneous movement and tremors, which indicate that other muscles systems are activating

- thalamus then projects onto both postcentral and precentral gyrus
- the upper motor neuron (UMN) in the precentral gyrus is activated
- UMN then enters the **pyramidal tract** before entering either:
    1) **Corticobulbar tract** – leads into brainstem, site of motor nuclei = cell bodies of cranial nerves
    - fibers cross over (decussate) to move muscles on opposite side from cortex (e.g. stroke)

2) **Corticospinal tract** – leads into spinal cord, site of lamina IX
= cell bodies of spinal nerves

Motor Nuclei

Cranial Nerve	Nucleus	Position	Muscles innervated	Developmental Origin
III	Oculomotor	Medial	***Superior Division***: levator palpebrae superioris, superior rectus and medial rectus ***Inferior Division*****:** inferior oblique and inferior rectus	Somite
IV	Trochlear	Medial	Superior oblique	Somite
V	Motor nucleus of V	Lateral	Masseter and muscles of mastication	Brachial arches
VI	Abducens	Medial	Lateral rectus	Somite
VII	Facial	Lateral	Muscles of facial expression	Brachial arches
IX + X	**Nucleus Ambiguus**	Lateral	Pharynx, larynx, esophagus and stylopharyngeal (IX)	Brachial arches
XII	Hypoglossal	Medial	Intrinsic muscles on tongue - styloglossus - hyoglossus - gerioglossus	Somite

Note: spinal accessory nerve (XI) is actually a spinal nerve from the cervical region that travels in the lateral corticospinal tract
- innervates sternocleidomastoid and trapezius muscles

IV. Cranial Nerves: Autonomic and Efferent Pathways

Note: cranial nuclei receive inputs from more than one source
e.g. voluntary but not involuntary facial paralysis

Parasympathetic Inputs
1. Salivary Glands
   - parotid
   - submandibular
   - sublingual
2.Mucous Glands of nose and oropharynx
3. In orbit:
- lacrimal gland
- sphincter and dilator muscles
- ciliary muscle
4. Thoracic and Abdominal Viscera
5. Blood Vessels

Sympathetic Pathways

- Preganglionic primary cell bodies in lamina VII (T1-T2)
- White ramus/sympathetic chain
- Superior Cervical Ganglion: postganglionic secondary cell bodies
- Axons follow blood vessels (tunica adventitia) to their targets

Parasympathetic Pathways

- extensive outflow driven by **hypothalamus**

Body

- axon from hypothalamus synapses in lamina VII with preganglionic neuron
- synapses in ganglia outside CNS with many postganglionic neurons
- amplification system: single preganglionic neuron causes widespread response in periphery

Head: CN III, VII, IX and X all have parasympathetic outflow

- axon from hypothalamus synapses in parasympathetic motor nucleus
- leave brainstem with cranial nerves
- synapses in parasympathetic ganglion to innervate smooth muscle/glands

1. CN III

- **Nucleus of Edinger Westphal**
- **Ciliary Ganglion**
- Ciliary muscle, Sphincter muscle of iris
- Clinical Correlation: Epidural hematoma: CN III impinged at origin
- afferent parasympathetic outflow impaired = dilated pupil

2. CN VII

- **Superior Salivary Nucleus**
- **1) Sphenopalantine Ganglion**
- lacrimal gland, mucous membranes of nose and mouth
- **2) Submandibular Ganglion**
- submandibular and sublingual glands

3. CN IX

- **Inferior Salivary Nucleus**
- **Otic Ganglion**
- Parotid glands (saliva production)

4. CN X

- **Dorsal Motor Nucleus**
- Thoracic and Abdominal viscera

Rules of Afferent Organization

1. With one exception, cell bodies of first order neurons are located in afferent ganglia **outside** CNS

2. No synapses in sensory ganglia; merely houses cell bodies
3. Afferent neurons are modality specific – pain, pressure, temperature, vibration, touch
4. In general, modalities are sorted within CNs

Body

- DRG houses first order neuron cell body
- Second order neuron in lamina II (pain) or cuneate/gracilis nucleus (touch)
- Third order neuron in VPL; connection to postcentral gyrus

Head

- V1, V2, V3 – trigeminal ganglion
- VII – geniculate ganglion
- IX – superior and inferior ganglion
- X – jugular nodosum ganglion

Trigeminal Ganglion

- *proprioception*: first order neuron cell body in **mesencephalic nucleus**
- *only nucleus with first order neuron*
- lesion to mesencephalic nucleus interrupts with ability to chew because of lack of awareness of tongue's position
- *touch*: **pontine nucleus** – projects to VPM
- *pain*: major alert system
- axons descend to spinal cord = **spinal tract of V**
- second order neuron cell bodies = **nucleus of spinal tract of V**
- some go to VPM: sharp but ephemeral pain
- others project to **Reticular Formation**: more serious pain, long lasting and diffuse

~ indicates major injuries/cancer; influenced by stress-induced analgesia

~ pathway works to dampen pain in emergency but stop working

- Reticular formation may project to laminar nucleus of thalamus
- don't respond to normal ways of treating pain (e.g. opiates)
- *visceral afferents*: via vagus – ganglion of IX or X
- solitary tract
- **solitary nucleus**
- at rostral end, detection of *taste*

1) Anterior 2/3 of Tongue – VII, geniculate ganglion
2) Posterior 2/3 of Tongue – IX, glossopharyngeal ganglion
3) Base of Tongue and Epiglottis – X, vagal ganglia

Clinical Correlations**:**

- Amygdala **–** site of one trial learning; most primitive form of memory
- direct projections from teeth
- Common carotid artery is subject to stenosis via athlerosclerosis
- internal carotid to middle cerebral feeds thalamus, basal ganglia and internal capsule through number of small arteries called striates
- small thrombus will have catastrophic effects

- ischemia: as neurons die, they release glutamate, causing nearby neurons to fire themselves to death
- treatment for stroke: glutamate blocker

V. Functional Anatomy of the Orbit

Spaces

- ethmoidal air cells
- maxillary sinus
    - these first two are especially delicate
- frontal sinus

e.g. squash ball will push eyeball into airspaces

Orbit

- two parallel medial borders
- lateral border – 45 angle

Rim

- frontal bone – thick
- maxilla – extends underneath globe
- zygomatic bone
- sutures – potential lines of fractuce (Le Fort I & II)

Inside Orbit

- orbital plate = lateral wall of orbit
- ethmoidal bone – very thin
- lacrimal
- palantine – small contribution to floor
- sphenoid – openings for all nerves into eye
    - superior orbital fissure
    - foramen rotundum – V2; transverses floor of orbit
    - pterygoid canal
    - foramen ovale – V3
    - optic canal

    Also contains:
    - sella turcica – contains the pituitary

Note: possible to put prosthesis inside capsule that surrounds globe

- in order to maintain size of orbit during growth, size of prosthesis must be increased
- therefore, the skull grows in response to soft internal structure

Soft Structures of the Eye

- **Canalicula** – collect tears from lacrimal gland
    - drain into lacrimal sac, then into internal meatus of nose
- **Conjunctiva**
    - mucosal membrane that lines inner eyelid and covers eye
    - highly vascularized

    - protects cornea
    - contains mucous glands that lubricate eye
- Lacrimal gland
    - produces tears that contain immunoglobulins, amino acids, salt and water
    - tears sweep across the surface to lubricate the eye
    - without tears, there would be ulceration of the mucosa
    - *Afferent*: lacrimal nerve (branch of CN V)
    - *Secretomotor*: zygomaticofacial nerve (from below)
    - *Sympathetic*: from blood vessels; no known function
- **Orbicularis oris muscle**
    - Palpebral portion tonically activated to protect the cornea during sleep
    - Orbital portion used during winking
    - Lacrimal portion squeezes lacrimal sac when eye closes
- **Orbital Septum**
    - fills in space around eyeball
    - continuations of periosteum; outer layer of dura mater
- **Medial and Lateral Palpebral Ligaments**
    - center the eye
    - attached directly to **tarsus** and bone
- **Tarsus**
    - Gives eyelid shape through its rigidity
- **Infraorbital Fat**
    - Metabolically spared
    - Starvation: *Enophthalmos* – eye sinks into orbit

    Vs.
    - Goiter: hypertrophy of thyroid gland causes *bilateral Exophthalmos*
        - may lead to **Grave's Disease** = persistent exophthalmos
    - Fistula in cavernous sinus: *unilateral Exophthalmos*

Muscles of the Eye

Muscle	Origin	Action	Innervation
Superior rectus	Annulus tendineus	Elevation	CN III
Inferior oblique	Lacrimal bone	Elevation	CN III
Inferior rectus	Annulus tendineus	Depression	CN III
Superior oblique	Sphenoid bone	Depression	**CN IV – trochlear**
Medial rectus	Annulus tendineus	Adduction	CN III
Lateral rectus	Annulus tendineus	Abduction	**CN VI - abducens**
Levator palpebrae superioris	Sphenoid bone	Raises upper eyelid; *acts on tarsus*	CN III

Notes:

- Origin of all *Rectus* muscles = **common tendinus ring**
    - Levator Palpebrae doesn't insert here
    - *Every nerve except trochlear nerve (CN IV) go through the ring*
- in the levator palpebrae superioris, there is also white muscle innervated by the sympathetic nervous system; this muscle is normally tonically contracted
- without it, *pseudotosis* results
- these same droopy eyelids and sunken eyes (enophthalmos) may be seen with severely decreased adrenal levels

Horner's Syndrome = disruption of superior cervical ganglion

- pseudotosis
- constricted pupil (no sympathetic response)
- sunken eyes (usually unilateral enophthalmos)

Afferent Nerves of the Eye – all branches of CN V1

Branch	Course	Innervates
Lacrimal nerve (Note: Receives parasympathetics from the pterygopalatine ganglion)	Superolateral (lateral to frontal nerve)	Lateral portions of eyelids and palpebral conjuctiva; *afferent innveration to* **lacrimal gland**
Subraorbital nerve (larger, terminal branch of **frontal** n.)	Passes out subraorbital notch onto forehead	Skin of eyelid, forehead and scalp
Supratrochlear nerve (branch of **frontal** n.)	Medial to supraorbital nerve	Skin of medial eyelid and central forehead
Short Ciliary nerves (1st branch of **nasociliary** n.)	Course back to trigeminal ganglion; may pass through ciliary ganglion	Posterior part of eyeball – corneal sensation: afferent part of blink reflex
Anterior ethmoidal nerve (2nd branch of **nasociliary** n.)	Through anterior ethmoidal foramen	Mucous membrane in nasal cavity; twig to *tip of nose* as external nasal nerve

Blink Reflex:

- Afferent = short ciliary nerves
- Efferent = CN VII
- Conjugal reflex – close both eyes

Ciliary ganglion

- receives *parasympathetic* fibers from inferior division of CN III
- originate in Nucleus and Edinger Westphal
- lateral to optic nerve
- connected to eyeball by short ciliary nerves: regulate sphincter of iris
- like all parasympathetic ganglia, hangs from CN V
- if interrupted by epidural hematoma, result = dilated pupil

Optic Nerve

- in the middle = central artery of the retina – occlusion = blindness
    - branch off ophthalmic artery
- therefore, increased pressure on the eye causes decreased heart rate = protective reflex

Eye Movements

- superior oblique tendon inserts behind equator
    - action = *down and out*
- inferior oblique
    - action = *up and out*
- lateral rectus inserts on equator
    - action = *out*
- medial rectus inserts on equator
    - action = *in*
- superior rectus
    - action = *up and in*
- inferior rectus
    - action = *down and in*

Eye Up – superior rectus and inferior oblique
Eye Down – superior oblique and inferior rectus
Diploplia – double vision; results from inactivation of any eye muscle