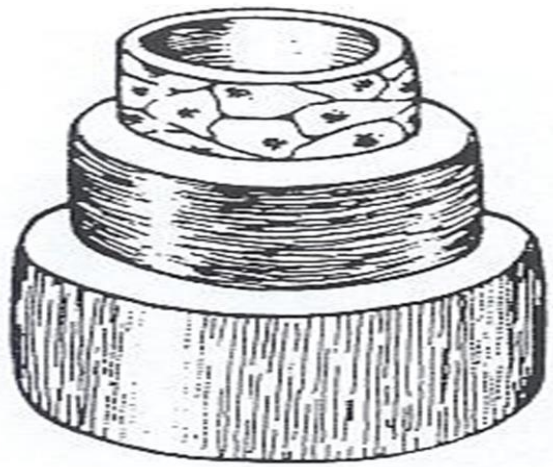
GROSS ANATOMY, PHYSIOLOGY, AND FLUID DYNAMICS OF THE CEREBROVASCULAR SYSTEM

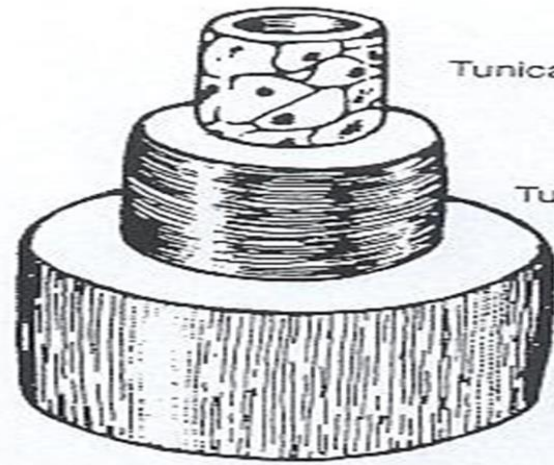
Chapter 18

Arterial Walls

- Composed of 3 layers or tunics:
  - Tunica Adventitia – outermost layer
  - Tunica Media – middle layer
  - Tunica Intima – innermost layer



Vein



Artery

Tunica Adventitia (Externa)

- Outermost layer
- Made up of elastic lamina enclosed by fibrous tissue
- The fibers that make up the elastic lamina run longitudinally and provide great elasticity to the arteries

Tunica Media

- Middle layer
- Composed of smooth muscular layer surrounded by fibrous tissue
- Muscular layer varies in thickness depending on the artery's function
- Muscle fibers are arranged in a circular pattern
  - Allows the muscular layer to better control the artery's diameter which regulates the flow of blood through the artery

Tunica Intima

- Innermost layer
- Composed of elastic lamina lined by a layer of endothelial cells that is one cell thick
- Endothelial cells on in the inner layer provide a smooth lining with no obstruction to blood flow
- Fibers course in a longitudinal pattern
- **Lumen** – the hollow center of the artery where blood courses

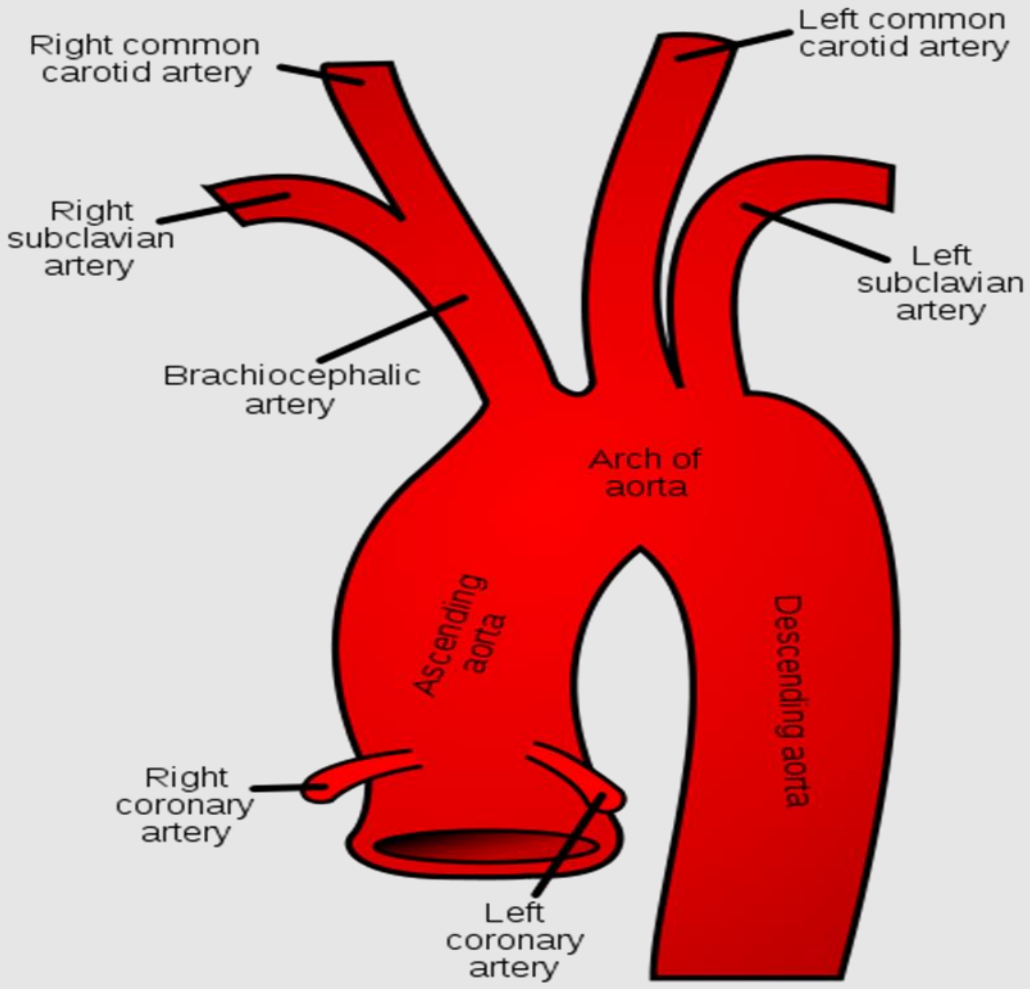
COMMON CAROTID ARTERY
TRAPEZOID IMAGING

Vasa Vasorum

- "Vessels of vessels"
- Tiny vessels in the *tunica adventitia* of both arteries and veins
- Provides the blood vessels with a source of nutrients as well as a conduit for waste products

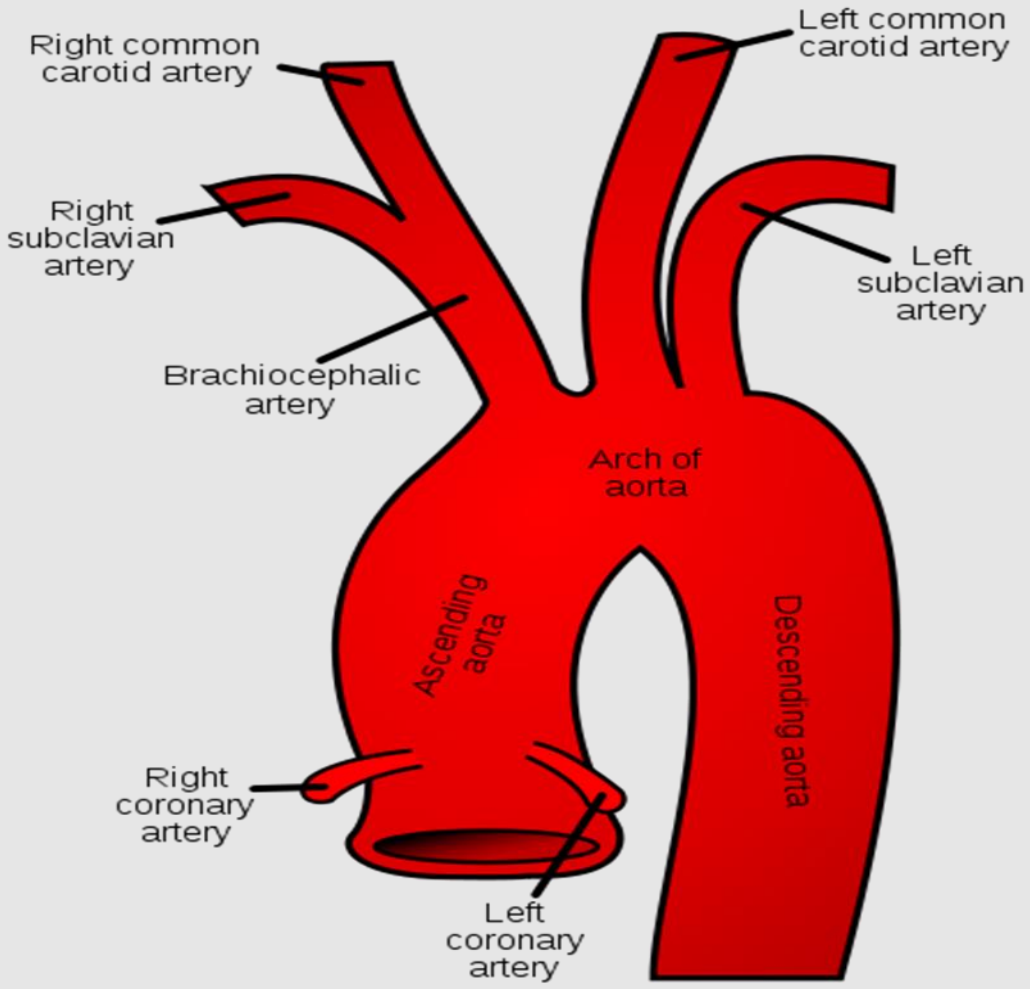
Ascending Aorta

- Arises from the left ventricle
- Has 2 branches (minor)
  - Right coronary artery
  - Left coronary artery



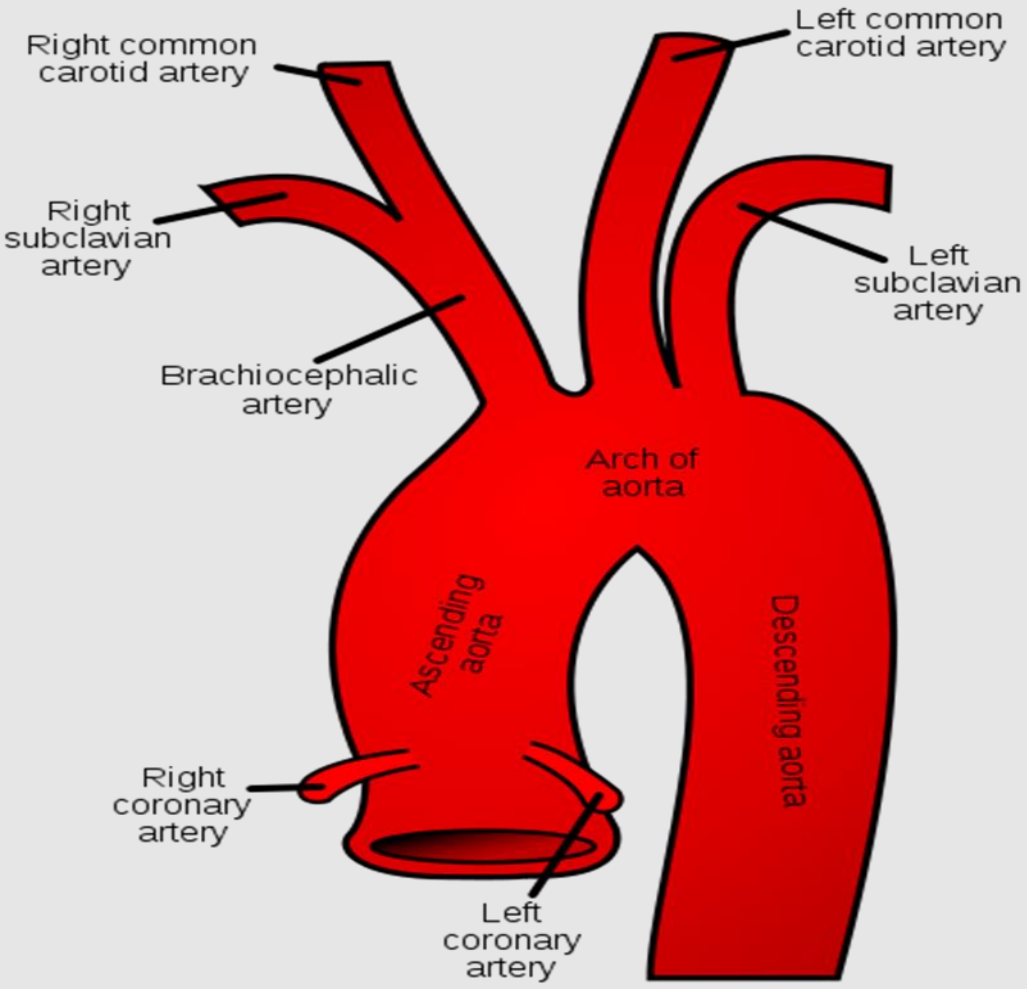
Aortic Arch

- Formed by the ascending aorta
- Has 3 branches (major)
  - Innominate
  - Left common carotid
  - Left subclavian



Descending Aorta

- Portion that extends from the aortic arch to just above the diaphragm



Aortic Arch Branches

1st - Innominate/Brachiocephalic Artery

- Arises from the right side of the transverse aortic arch behind the junction of the clavicle and sternum
- Bifurcates into *Right Subclavian* and *Right CCA*

- Right Subclavian Artery
  - Arises from the Innominate Artery laterally after traveling cephalad for 4-5 cm
- Right Common Carotid Artery
  - Arises from the Innominate Artery coursing proximally towards the brain
  - Bifurcates into the *Internal* and *External Carotid Arteries*

Aortic Arch Branches

2nd – Left Common Carotid Artery

- Arises directly from the transverse aortic arch

3rd - Left Subclavian Artery

- Arises directly from the transverse aortic arch

- Both the Left Common Carotid and Left Subclavian Arteries pass posteriorly behind the Left Sternoclavicular Joint

COMMON CAROTID ARTERY
TRAPEZOID IMAGING

COMMON CAROTID ARTERY
TRAPEZOID IMAGING

Pathways of Cerebrovascular Flow

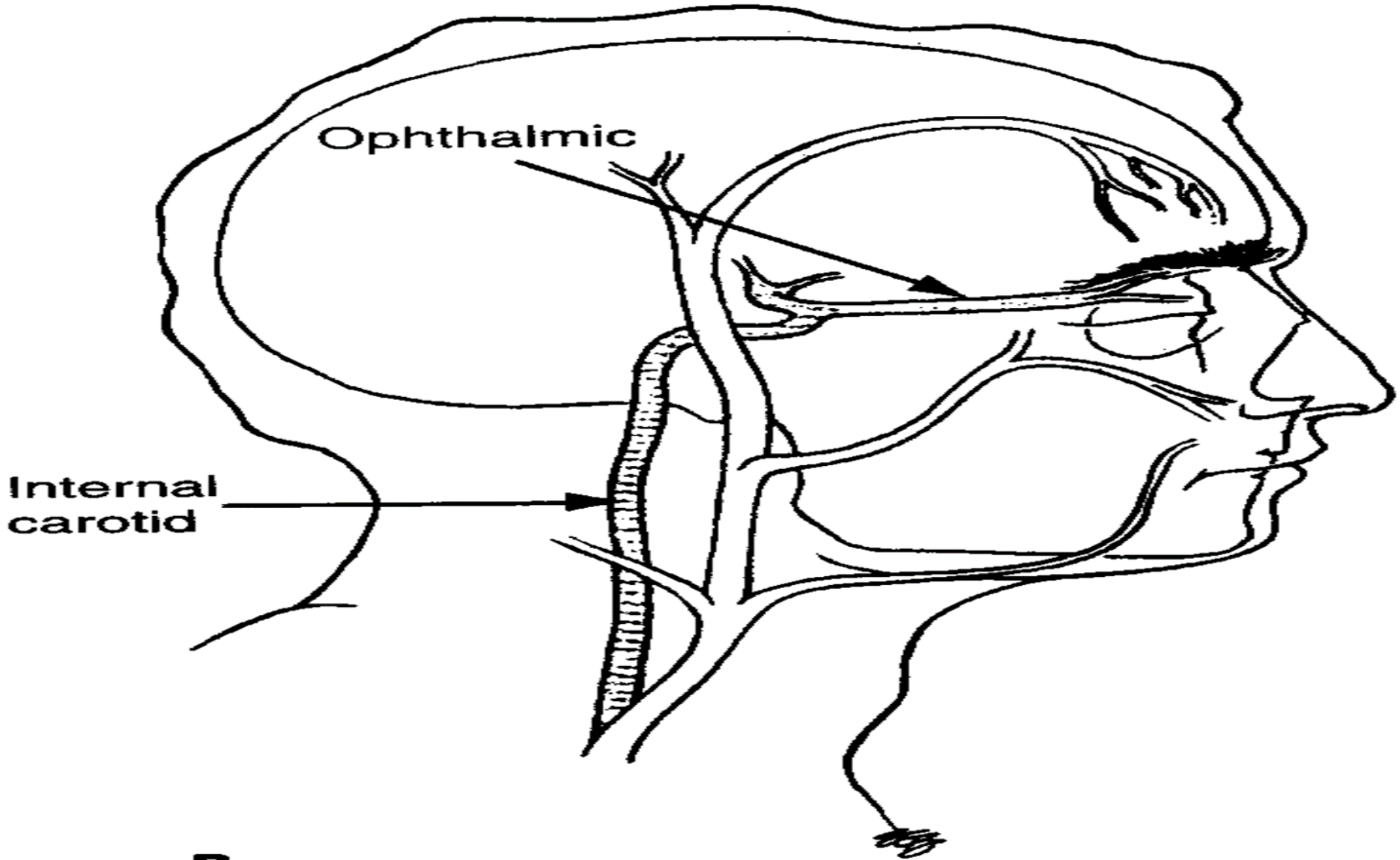
- Two major pathways for circulation to navigate the brain:
  - 1. Anterior circulation
  - 2. Posterior circulation
- Other alternative options in the event of a blockage in the major pathways:
  - 1. Periorbital circulation
  - 2. Collateral pathways

Common Carotid Artery

- Left and right common carotid arteries ascend the neck medially to the jugular veins
- Left CCA is typically longer than the right CCA due to its origination from the aortic arch
- Terminates into the internal carotid artery (ICA) and external carotid artery (ECA) in the area of the thyroid cartilage
  - Bifurcation can vary patient to patient – higher or lower
- At the bifurcation, there is a slight dilation
  - "Carotid bulb"

Anterior Circulation

- **Internal Carotid Artery (ICA)**
  - Originates from the Common Carotid Artery (CCA)
  - Travels into the base of the skull *without* branching
    - Once inside the skull, has three intracranial branches:
      1. Ophthalmic artery
      2. Anterior Choroidal artery
      3. Posterior Communicating artery
    - Terminates into Middle Cerebral artery (MCA) and Anterior Cerebral artery (ACA)



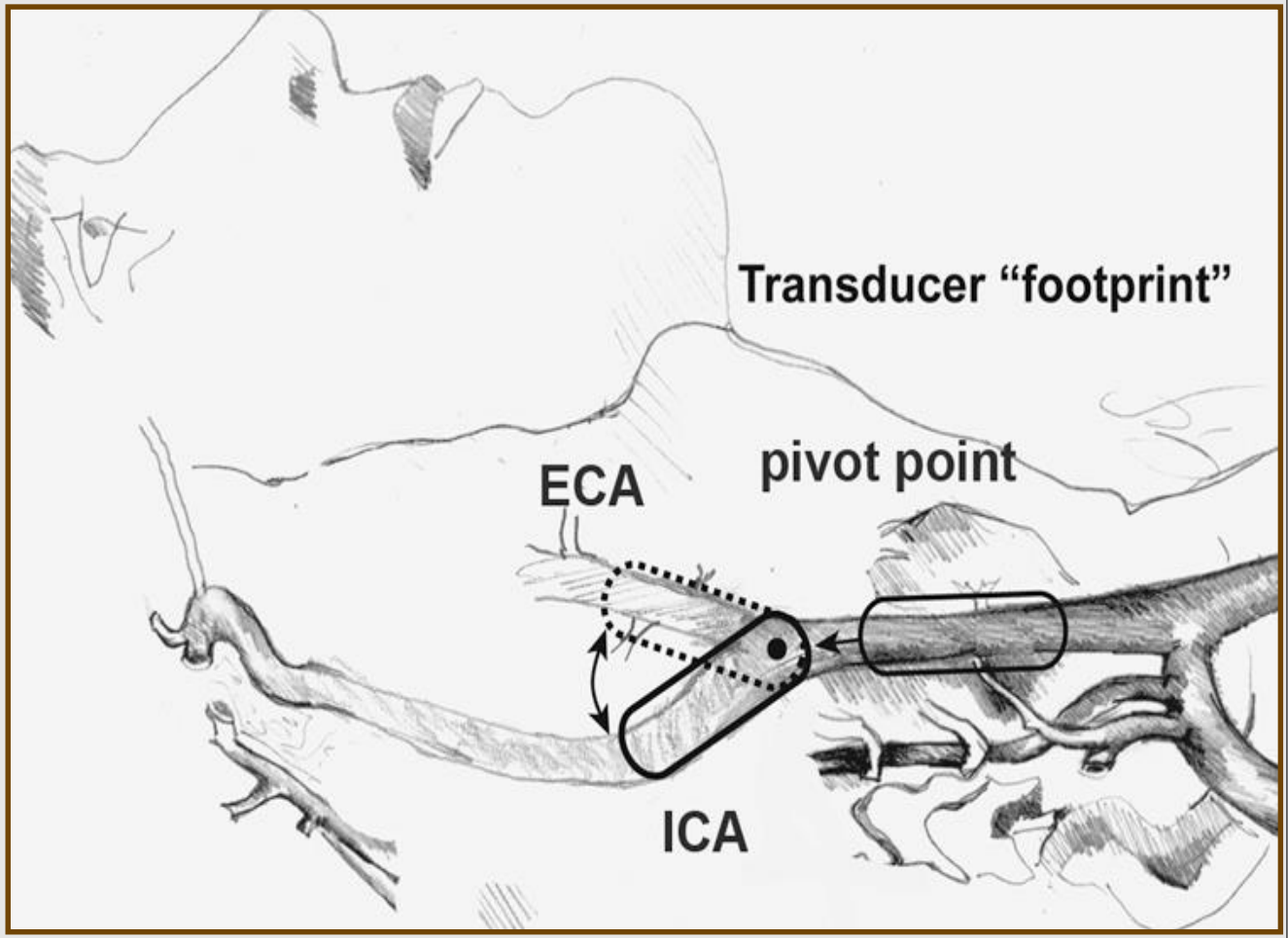
B

Internal Carotid Artery (ICA)

- Distributes blood to:
  - Ipsilateral cerebral hemisphere (anterior brain)
  - Eyes
  - Forehead
  - Nose
- Distributes blood to:
  - *Low-resistance* vascular beds

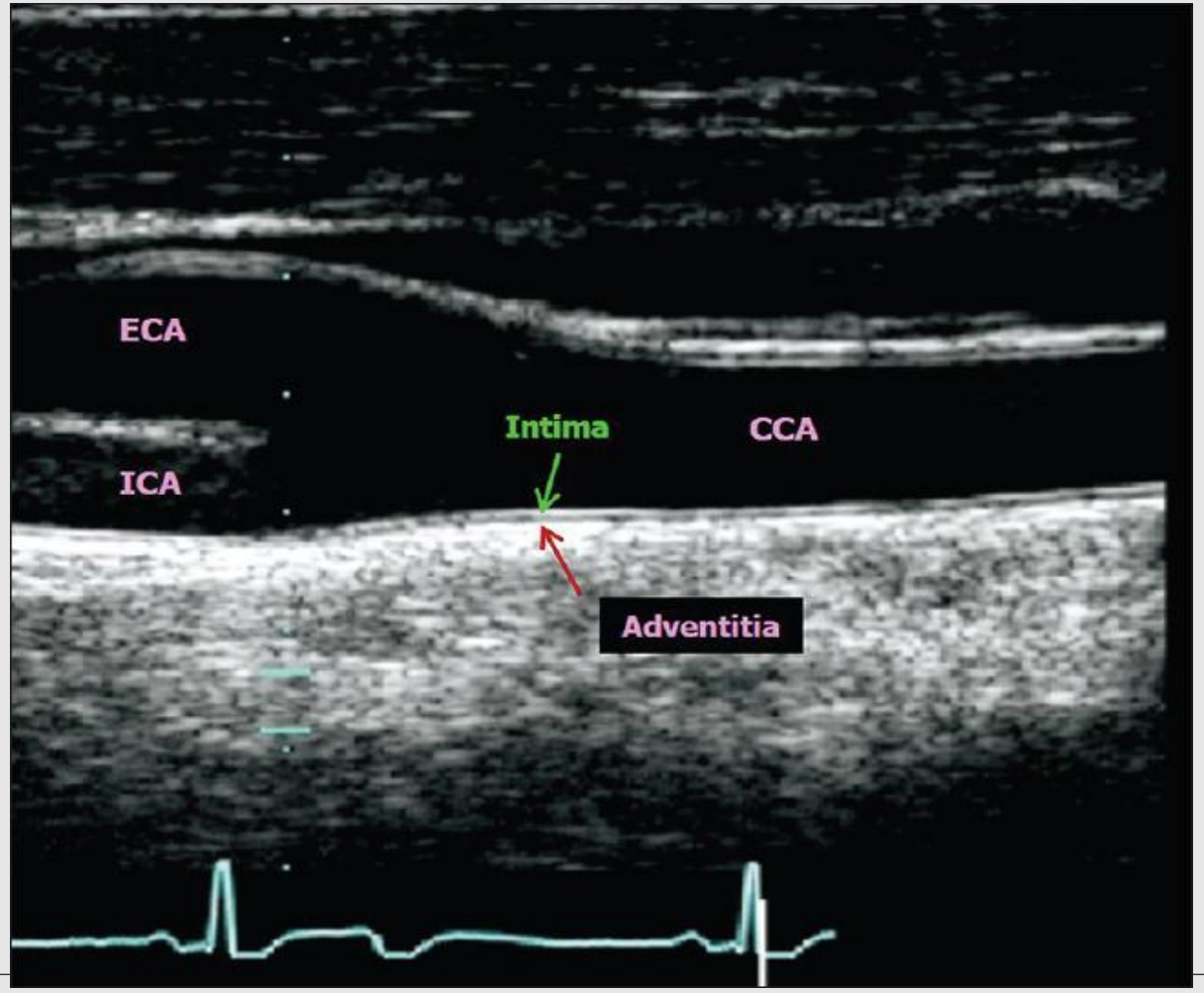
Internal Carotid Artery (ICA)

- Usually the larger and more lateral and posterior of the two branches of the CCA
  - This may vary by patient!
- Receives nearly 80% of the blood flow in the CCA



External Carotid Artery (ECA)

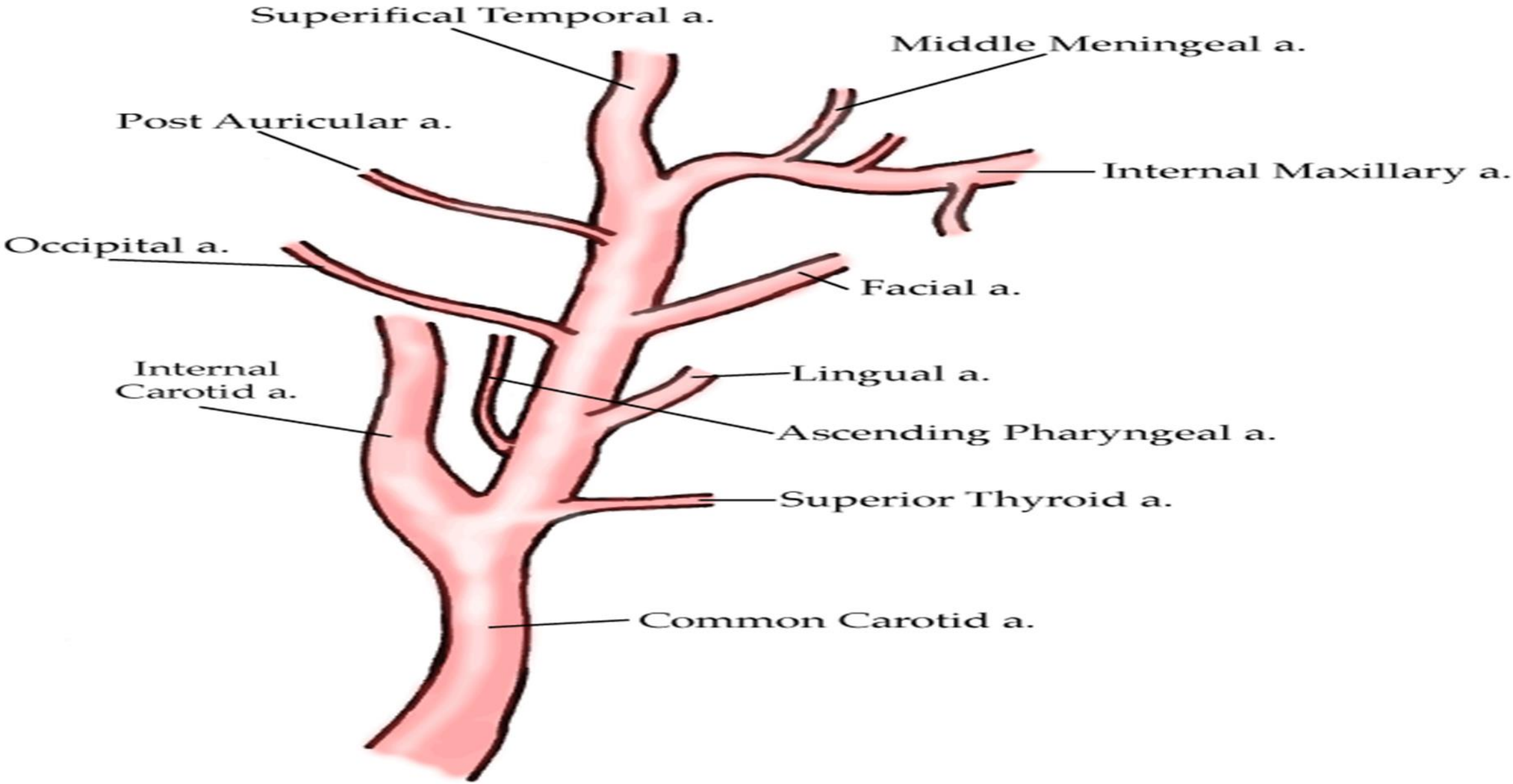
- Originates from CCA
- Usually smaller and more medial of the two branches of the CCA
- Supplies blood to the neck, face, and scalp

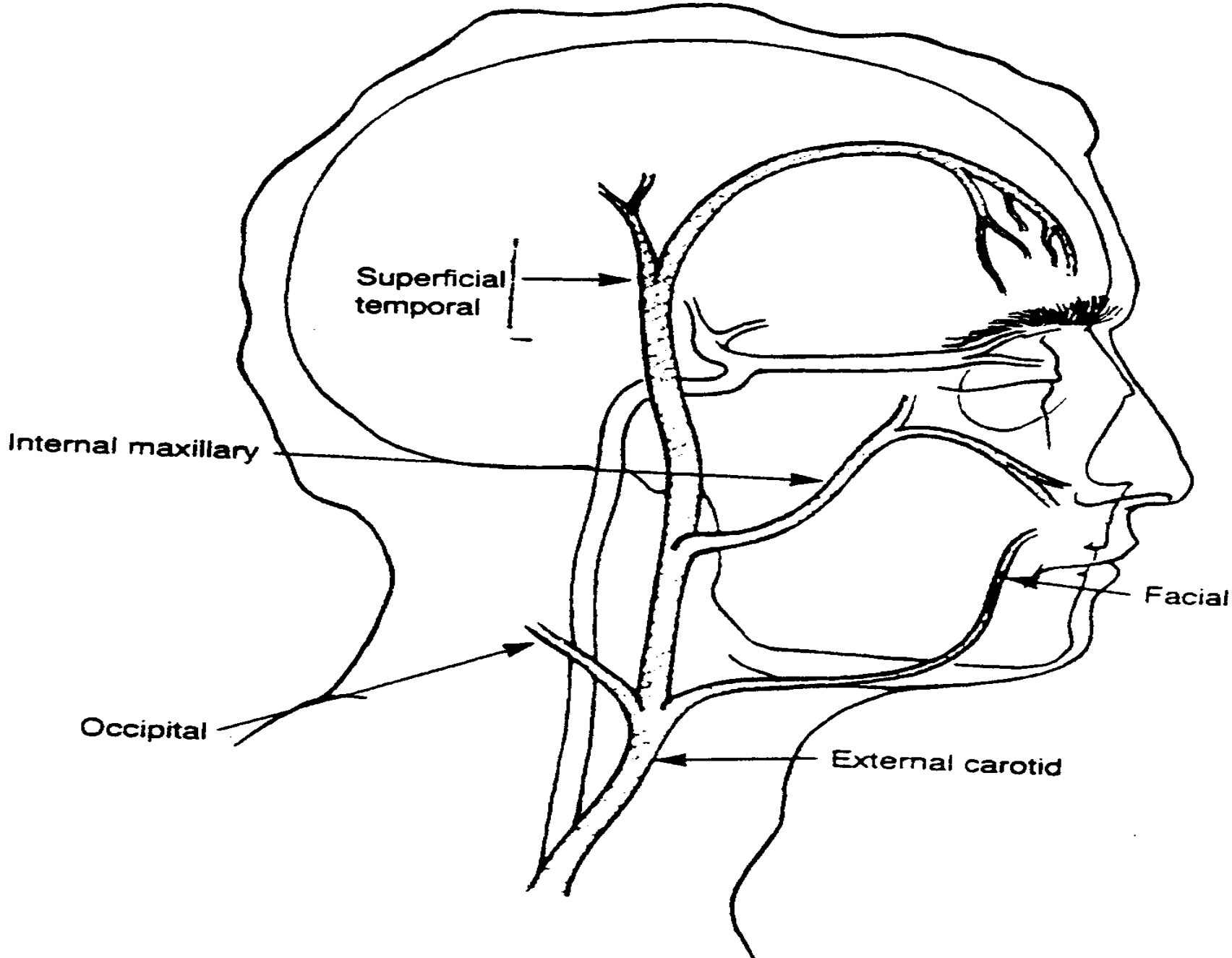


External Carotid Artery (ECA)

- Has ***eight*** branches:
  - Superior Thyroid Artery
  - Ascending Pharyngeal Artery
  - Lingual Artery
  - Occipital Artery
  - Facial
  - Posterior Auricular Artery
  - Superficial temporal artery
  - Maxillary Artery

Branches of External Carotid Artery

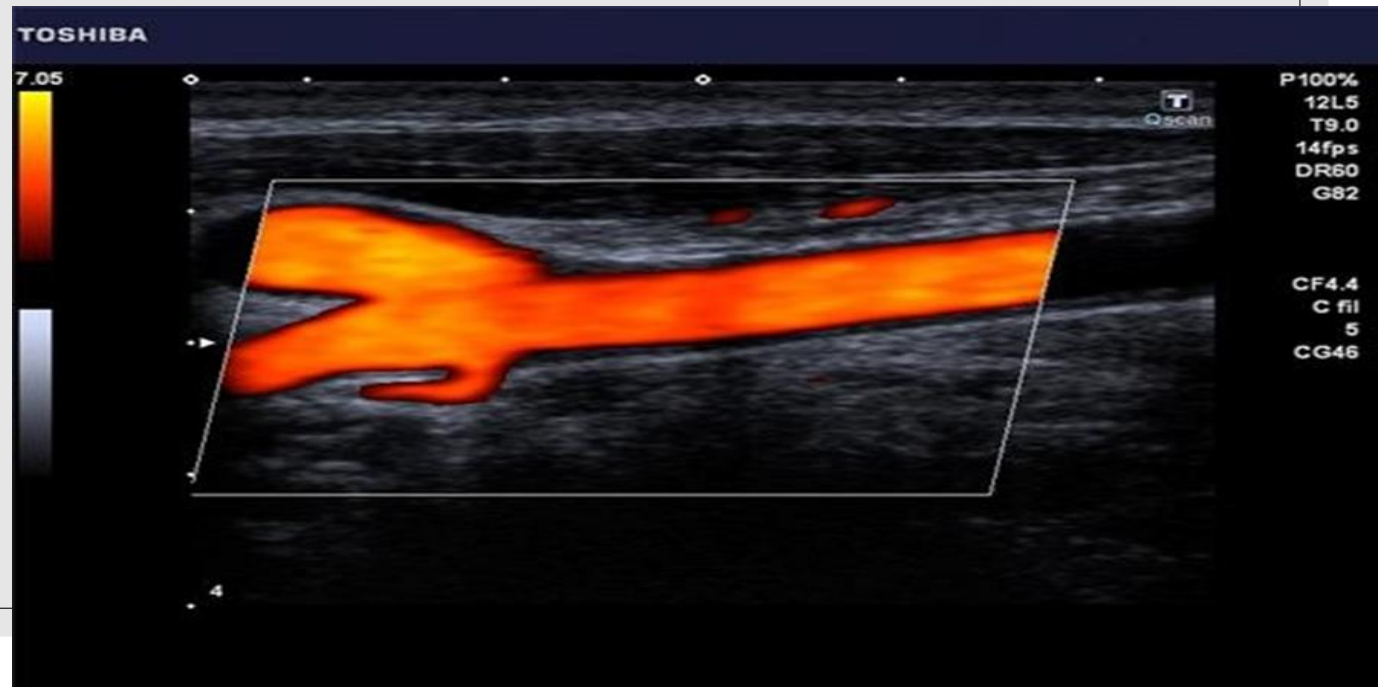



Superficial temporal
Internal maxillary
Facial
Occipital
External carotid

External Carotid Artery (ECA)

- Distributes blood to *high-resistance* vascular beds
- Identification of the ECA branches is the most important means of differentiating the ECA from the ICA

- **1st Branch: Superior Thyroid Artery**




HDI 5000
L12-5 38 CVasc/Car
4:51:20 pm
TIs 0.2
MI 0.7
Fr #1
3.9 cm
Map 2
150dB/C3
Persist Low
Fr Rate High
2D Opt:Gen
ATL
CAROTID BIFURCATION

External Carotid Artery (ECA)

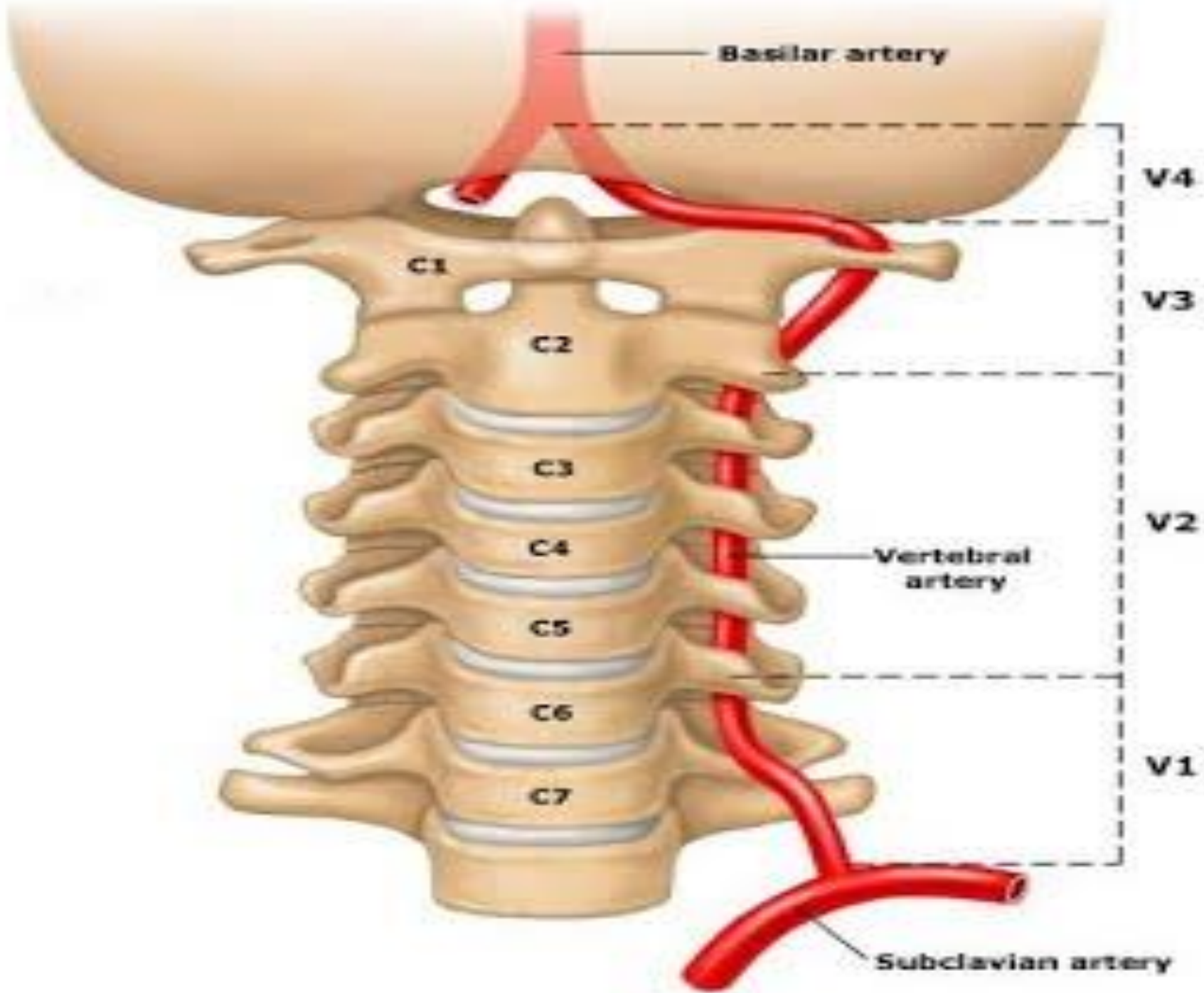
- The ECA branches are of no significance to the cerebral circulation except in the instance of cerebral or vertebral occlusive disease, at which point they may become an important source of collateral flow
- Any of the ECA branches may act as a collateral when the ICA is highly stenosed or occluded

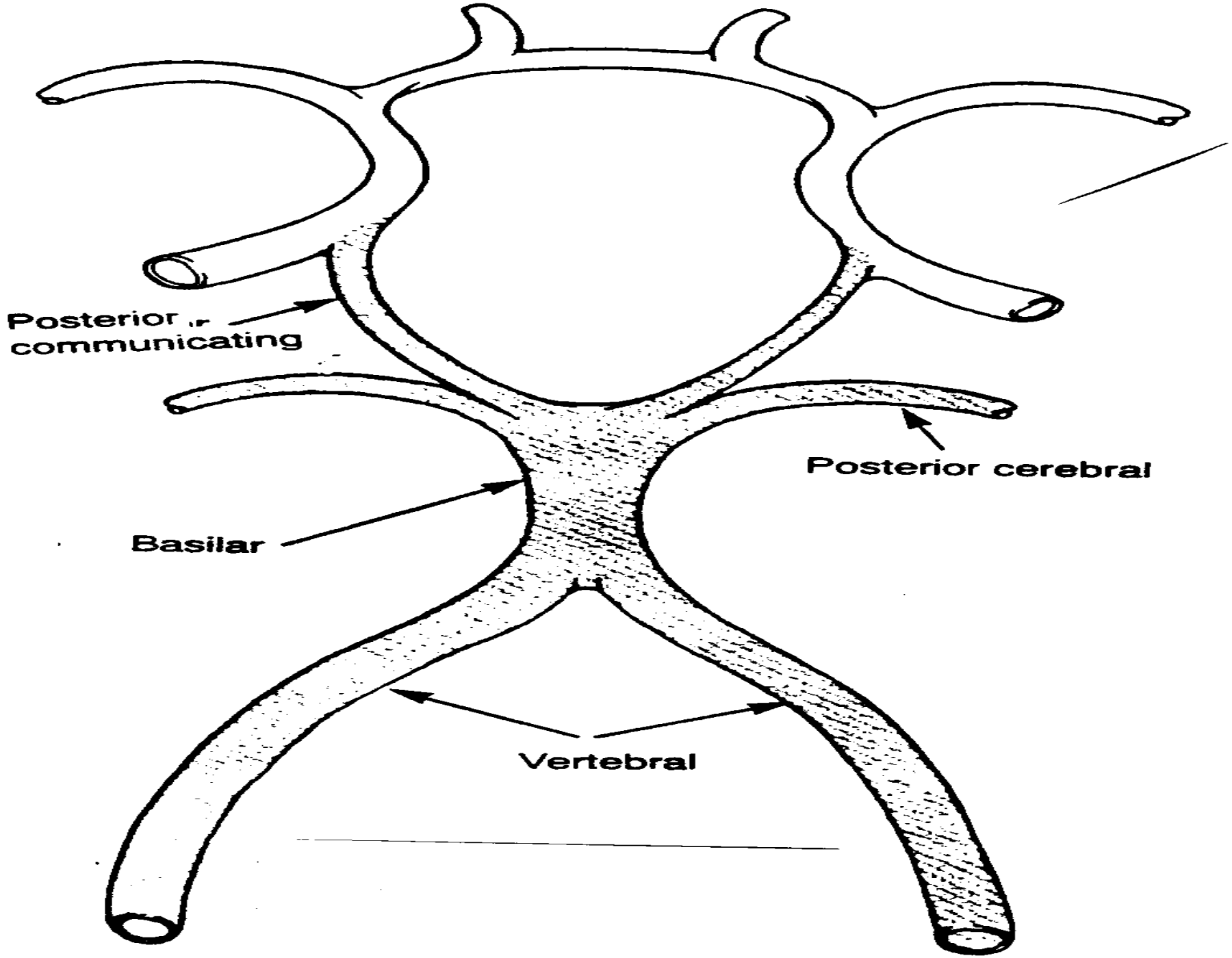
Posterior Circulation

- **Right and Left Vertebral Arteries**:
  - Arise from the Subclavian Arteries bilaterally
  - Asymmetric: right is usually smaller than left
  - Enters the transverse foramen of C6, courses cephalad through the transverse foramen of C6-C1
  - Unite after entering the skull through the foramen magnum to form the basilar artery

Posterior Circulation

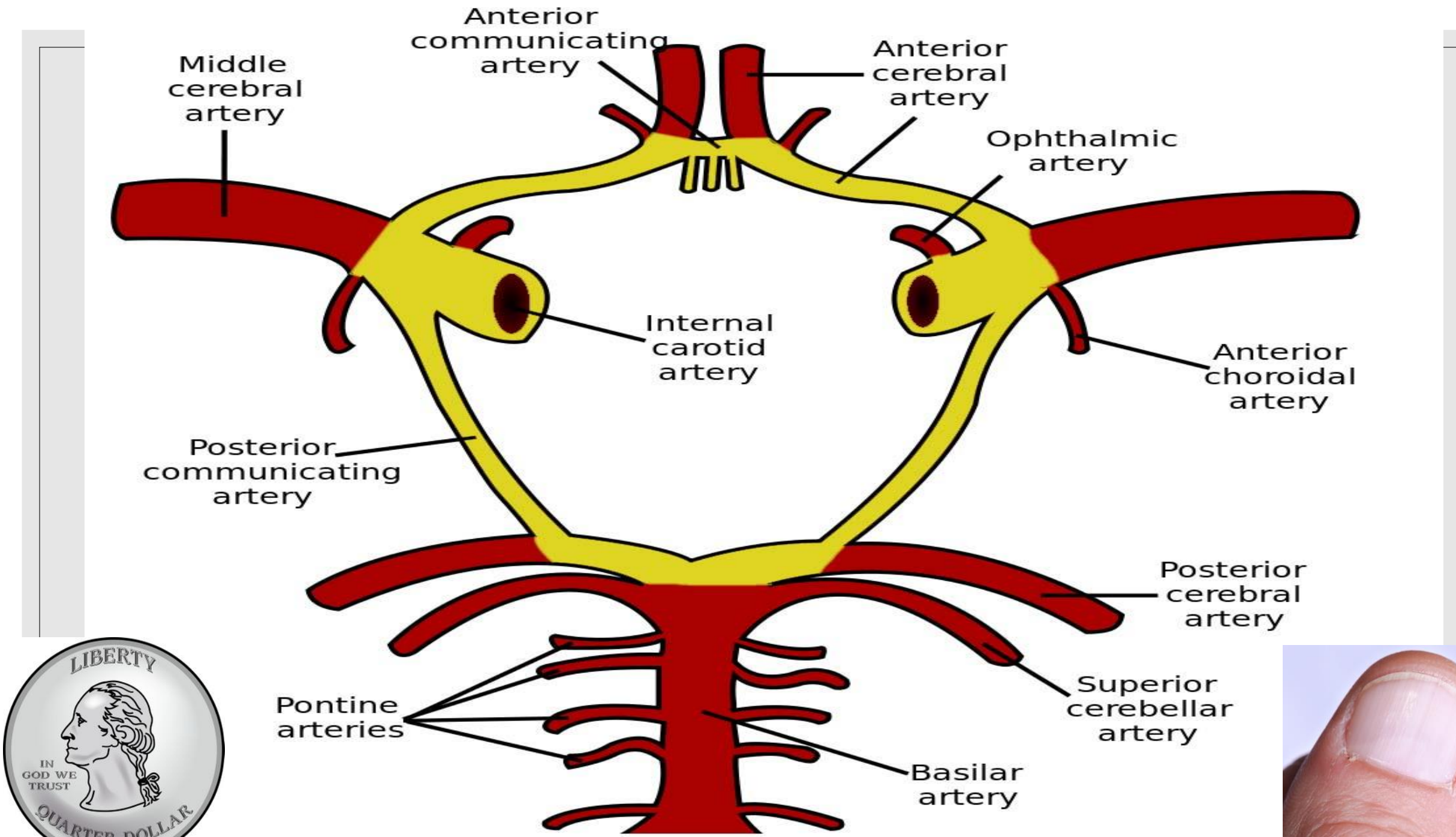
- **Basilar Artery**:
  - Formed by the confluence of the right and left vertebral arteries
  - Divides into the posterior cerebral arteries to form the circle of Willis
  - Supplies the posterior structures of the cranial cavity with blood


Basilar artery
V4
C1
V3
C2
C3
V2
C4
Vertebral artery
C5
C6
V1
C7
Subclavian artery


Posterior
communicating
Posterior cerebral
Basilar
Vertebral

Circle of Willis

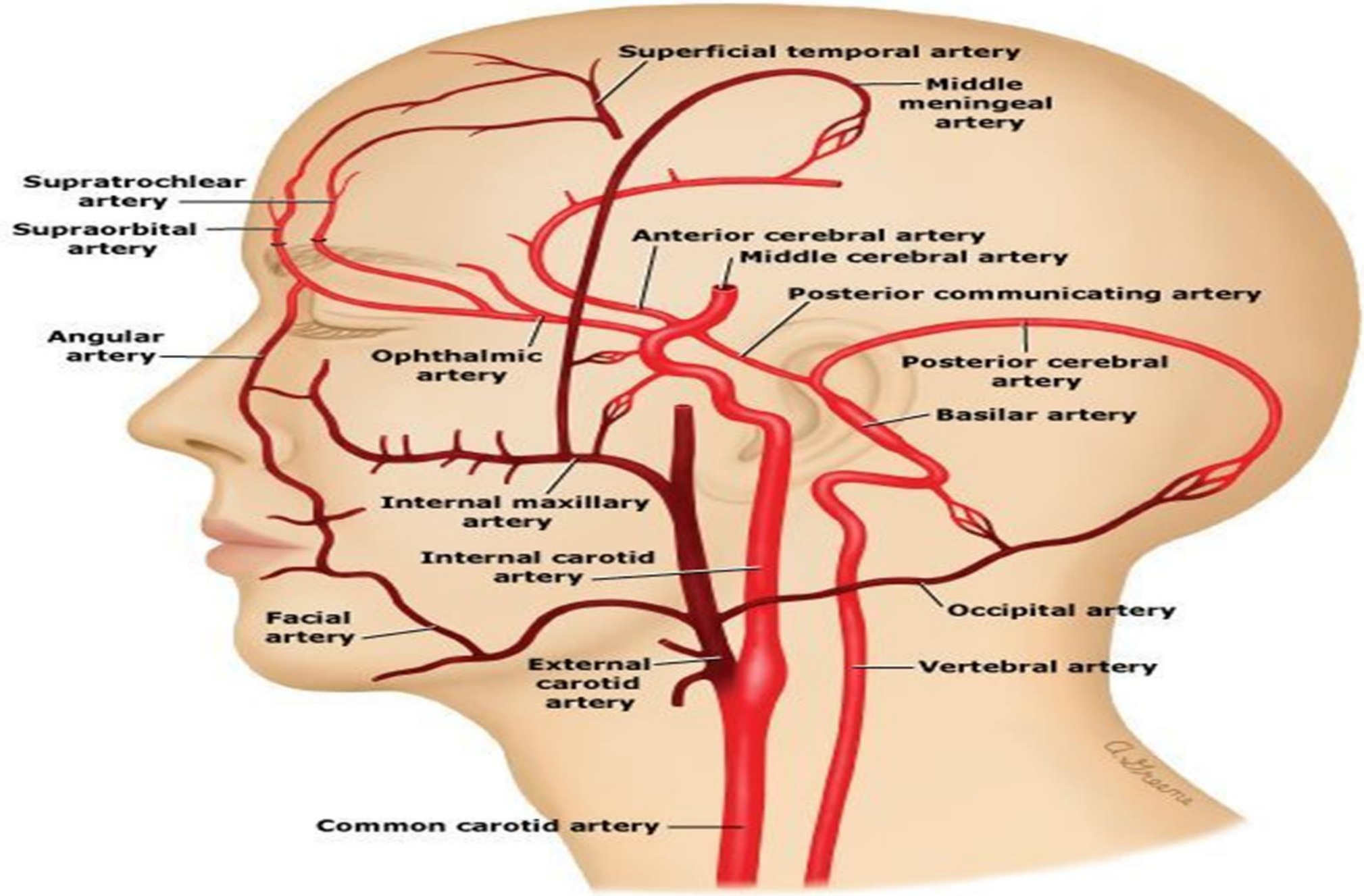
- Formed in front by the Anterior Cerebral Arteries (ACA)
- Formed in back by the 2 Posterior Cerebral Arteries (PCA)
- Hexagonal arrangement:
  - Anteriorly – ACA's are joined by the Anterior Communicating Artery (AcoA)
  - Posteriorly – Basilar Artery divides into 2 PCA's, each joined to the ipsilateral ICA by a Posterior Communicating Artery (PcoA)


Anterior communicating artery
Middle cerebral artery
Anterior cerebral artery
Ophthalmic artery
Internal carotid artery
Anterior choroidal artery
Posterior communicating artery
Posterior cerebral artery
Superior cerebellar artery
Pontine arteries
Basilar artery

LIBERTY
IN GOD WE TRUST
QUARTER DOLLAR

Periorbital Circulation

- Collateral vessels that connect the Anterior and Posterior circulatory systems in the event of a complete occlusion
- Major branches of the ophthalmic artery (branch off the ICA) are crucial in acting as collaterals from the ECA to ICA and from ICA to Posterior Circulation


Superficial temporal artery
Middle meningeal artery
Supratrochlear artery
Supraorbital artery
Anterior cerebral artery
Middle cerebral artery
Posterior communicating artery
Angular artery
Ophthalmic artery
Posterior cerebral artery
Basilar artery
Internal maxillary artery
Internal carotid artery
Occipital artery
Facial artery
External carotid artery
Vertebral artery
Common carotid artery

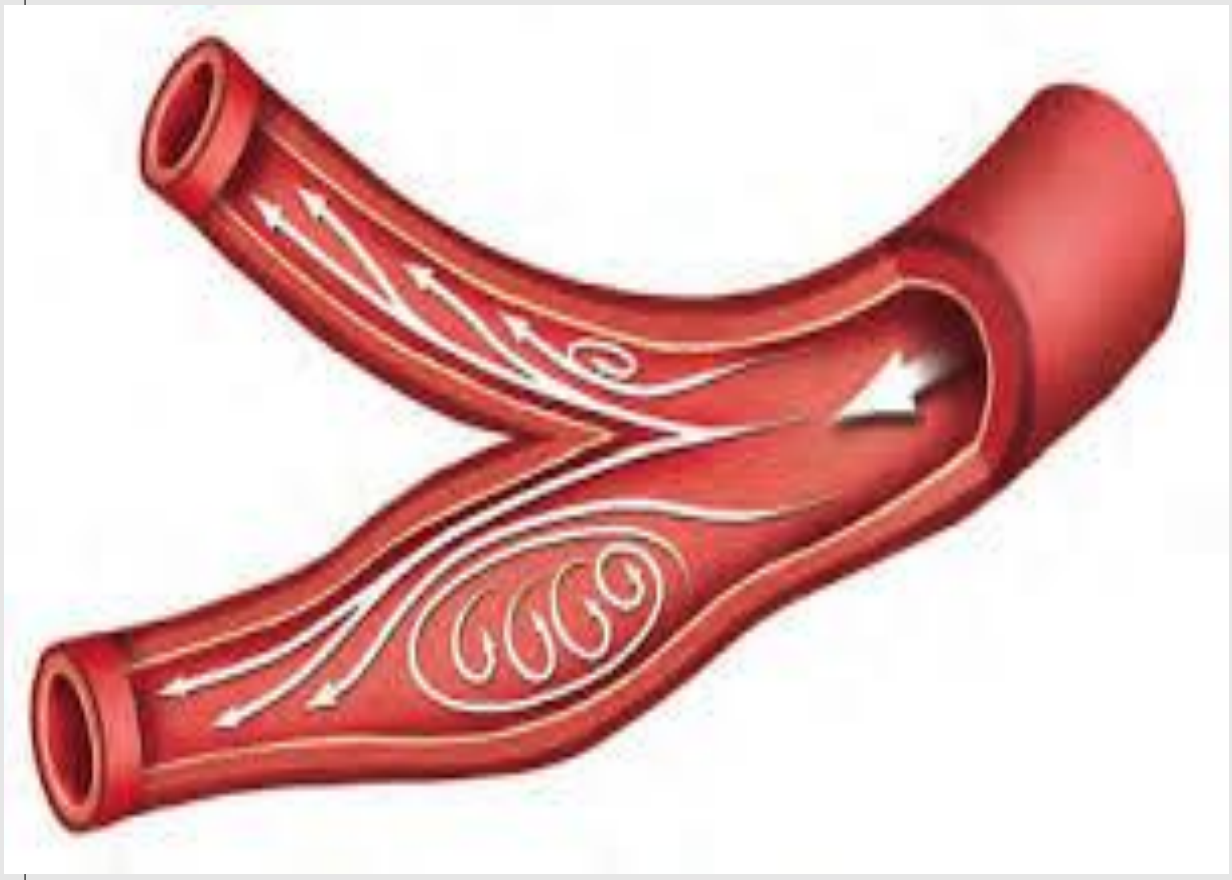
Collateral Pathways

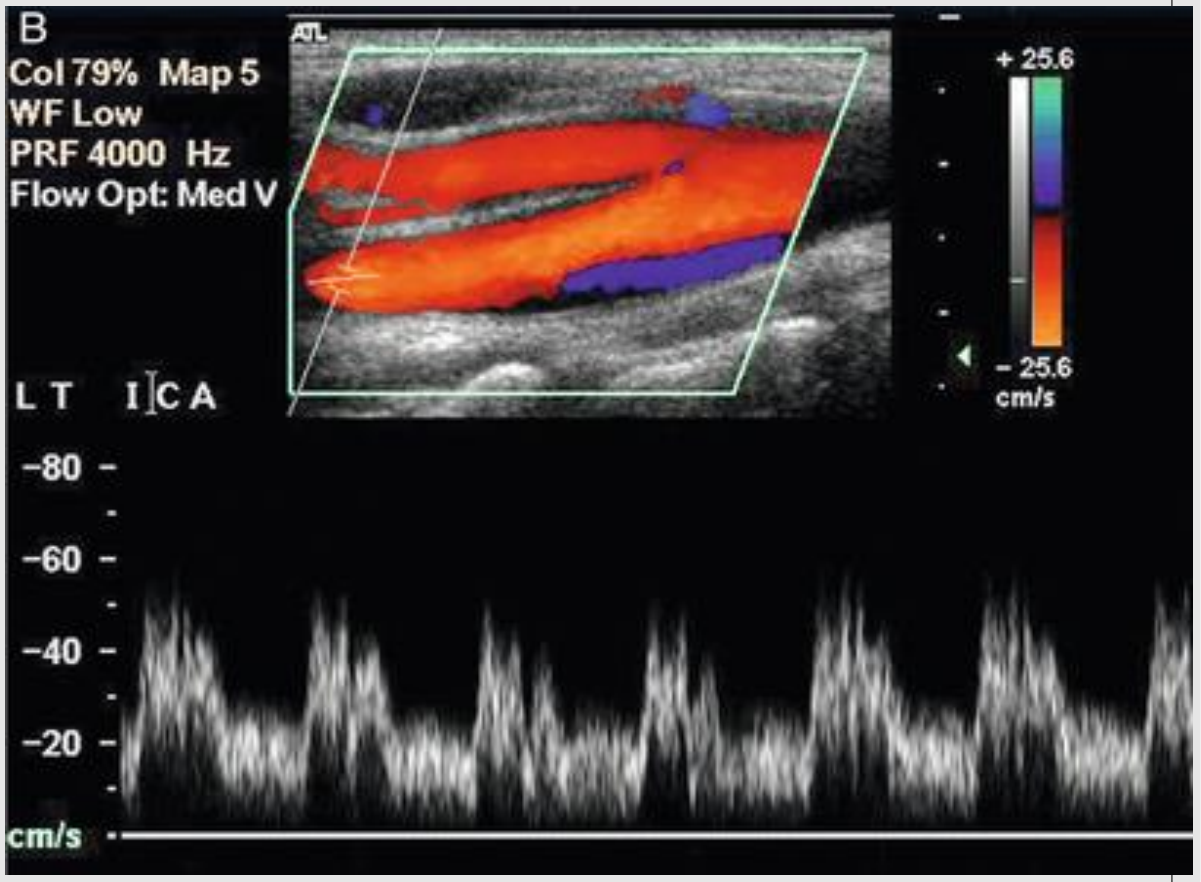
- Largest inter-arterial connections is the circle of Willis
  - A patient can have an occluded ICA and be asymptomatic because of collateralization via the cerebral communicating arteries!!
- ICA-ECA connections are through multiple branches to help with cross-collateralization

Pressure/Flow Relationships

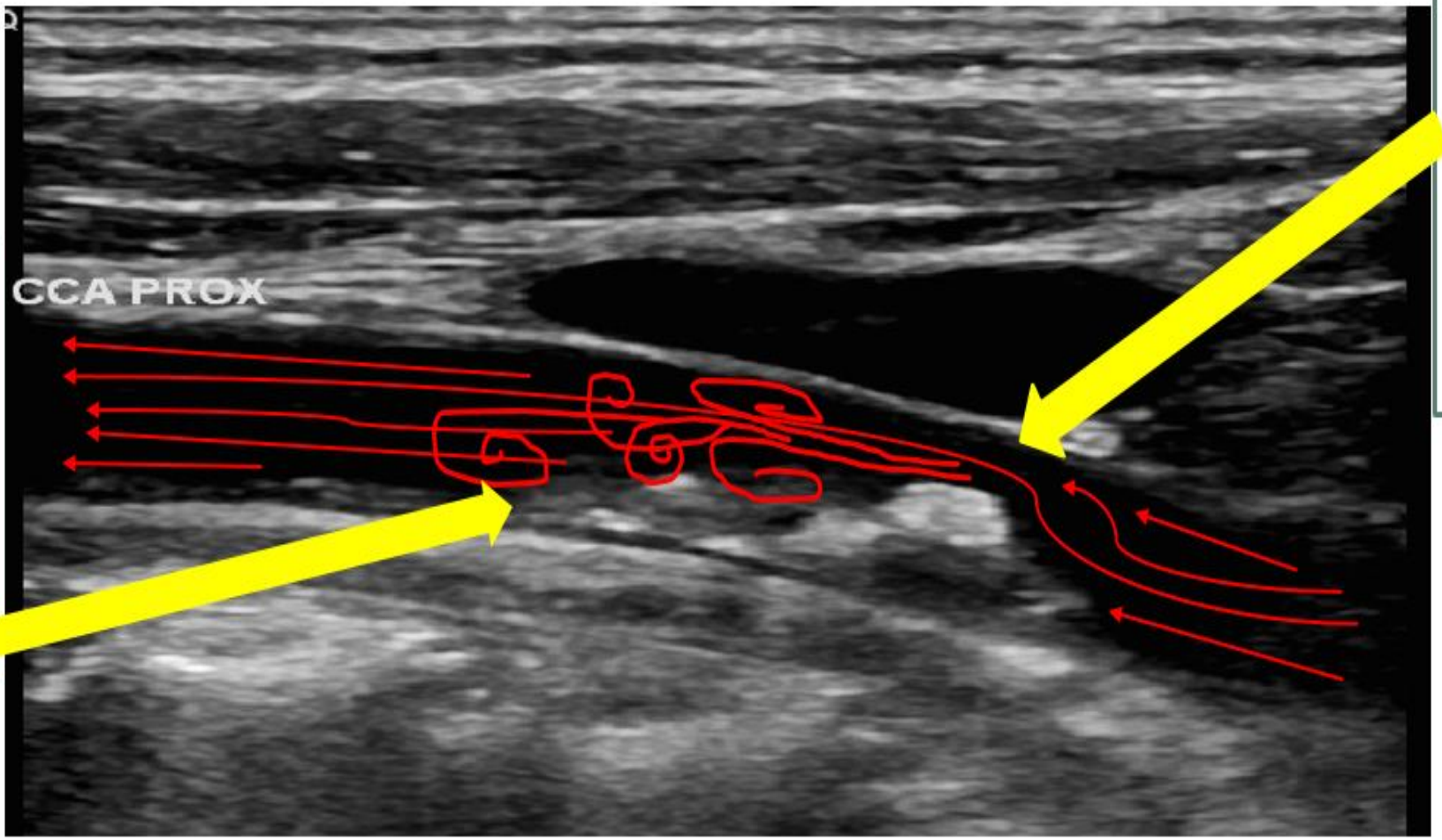
- **Bernoulli Principle**:
  - Total fluid energy along a streamline of fluid flow is constant
  - Velocity energy and Pressure energy are inversely proportional
    - ↑ velocity means a ↓ pressure
  - Small changes in geometry or direction of the vessel will cause a change in pressure gradients

Carotid Bifurcation





Bernoulli Principle



Velocity Decreases; Pressure Increases

Velocity Increases; Pressure Decreases

Pressure/Flow Relationships

- **Poiseuille's Law**:
  - Describes flow through a rigid tube as parabolic or laminar:

$$Q = \frac{(P_1 - P_2)\,\pi r^4}{8\,\eta L}$$

Q = Volume Flow
P_1 = Pressure at proximal end of vessel
P_2 = Pressure at distal end of vessel
r = radius of vessel
L = length of the vessel
η = viscosity of the fluid

Pressure/Flow Relationships

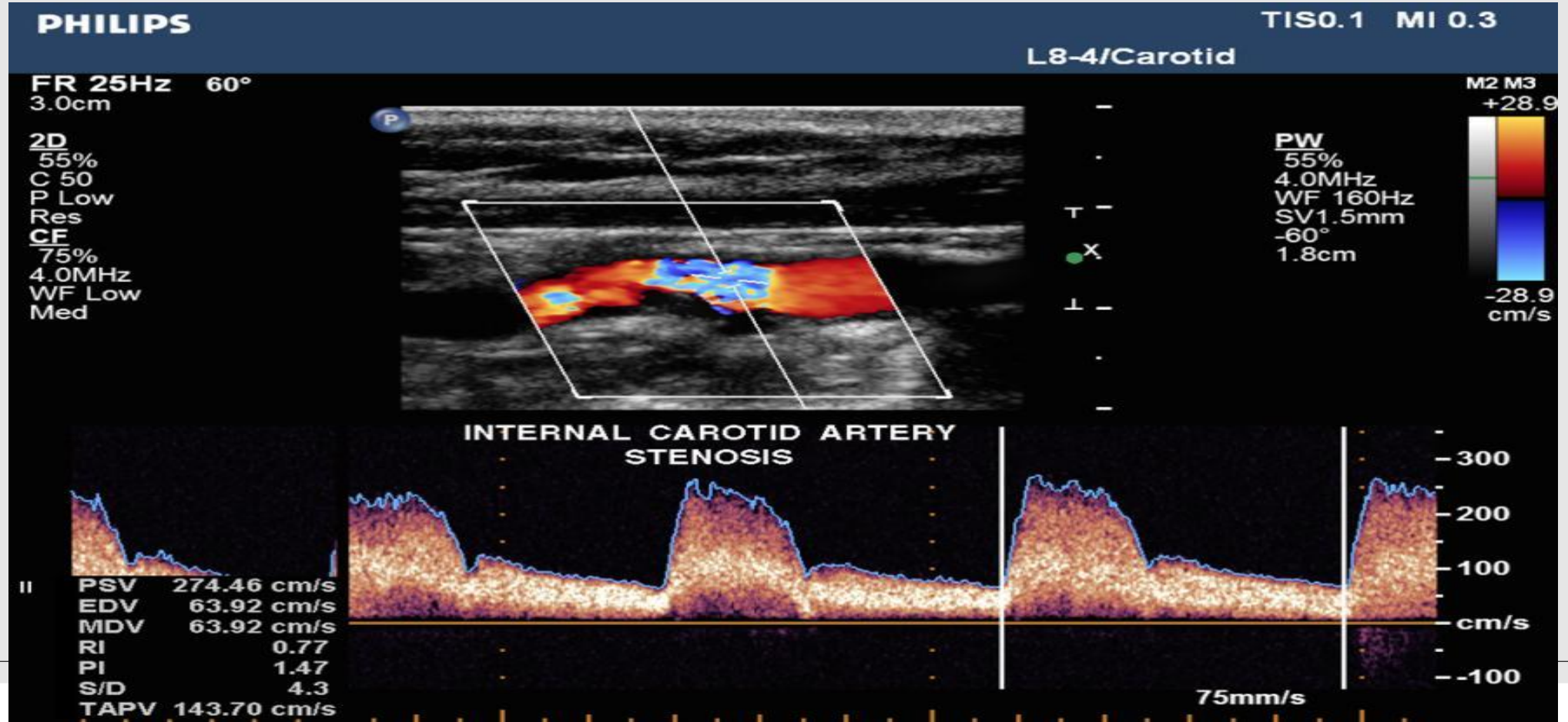
- **Poiseuille's Law**:
  - Flow is directly proportional to a pressure gradient and the size of the vessel
  - Flow is inversely proportional to the viscosity of the blood and length of the vessel
  - Small changes in the radius of the vessel will result in large flow changes

Effects of Stenosis on Flow

- Hemodynamically significant stenosis causes a reduction in volume flow and pressure
  - Blood must change velocity as the flow stream narrows at the stenosis and enlarges as it exits the stenosis
    - Causes turbulence, eddy currents, and vortices

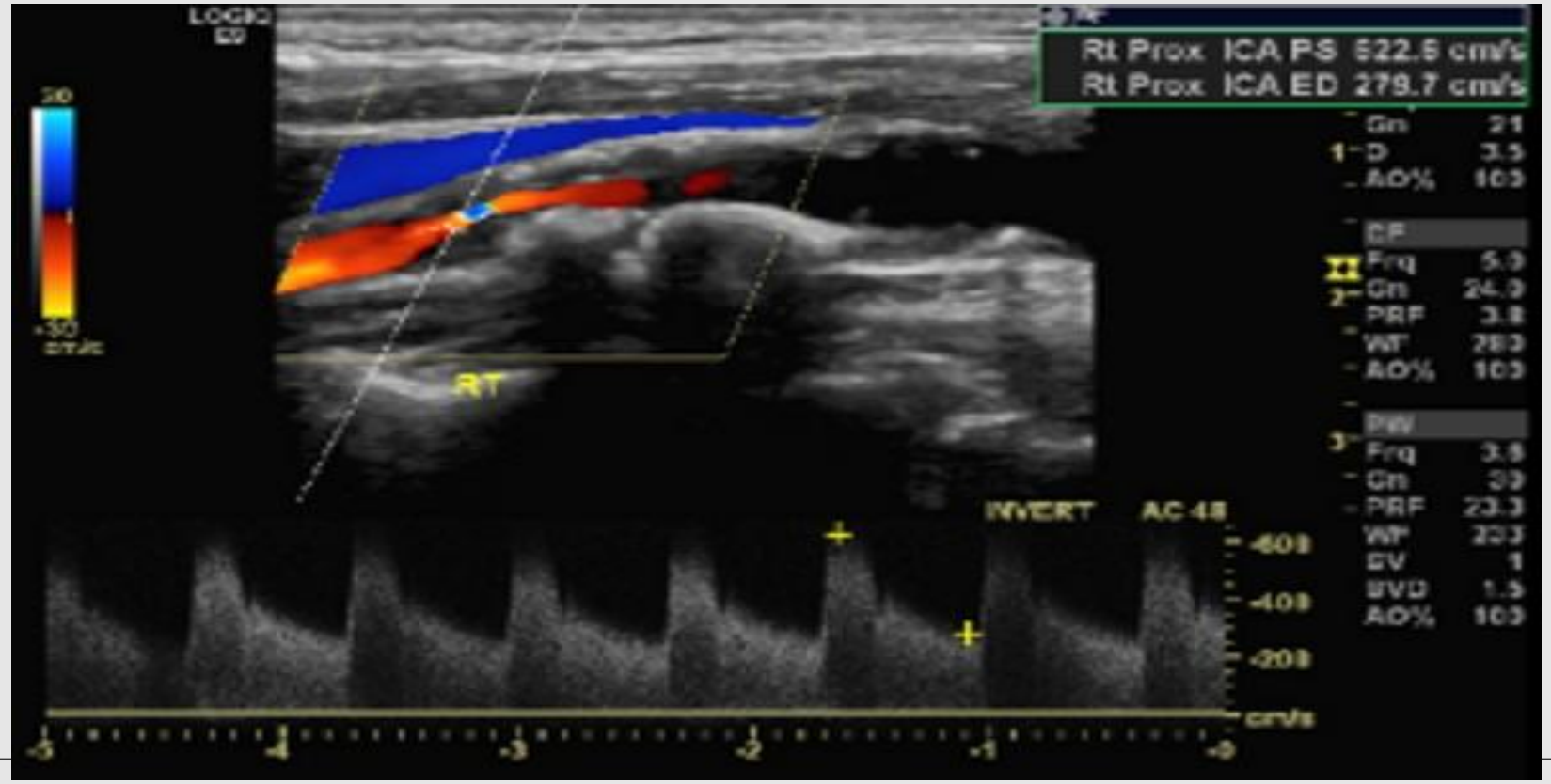
Effects of Stenosis on Flow

- Turbulence is detected by spectral broadening in your waveform and by aliasing in your color Doppler

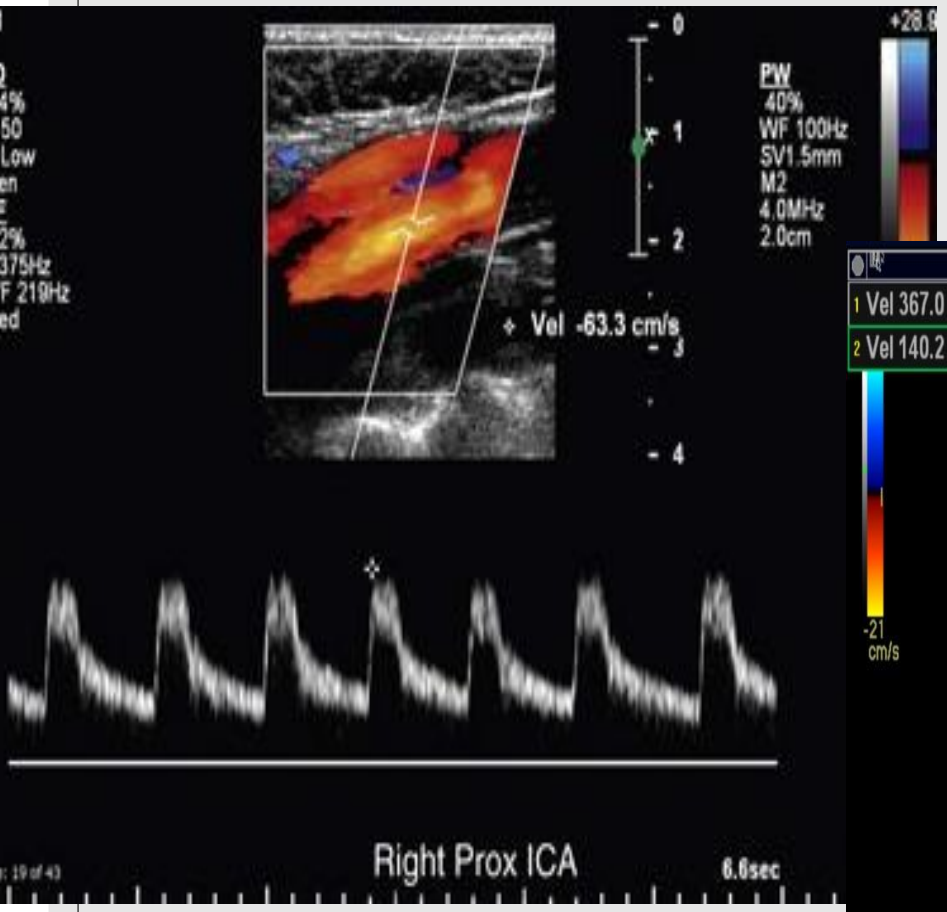


Effects of Stenosis on Flow

- Acceleration is reflected as increased frequency or increased velocity measurements.

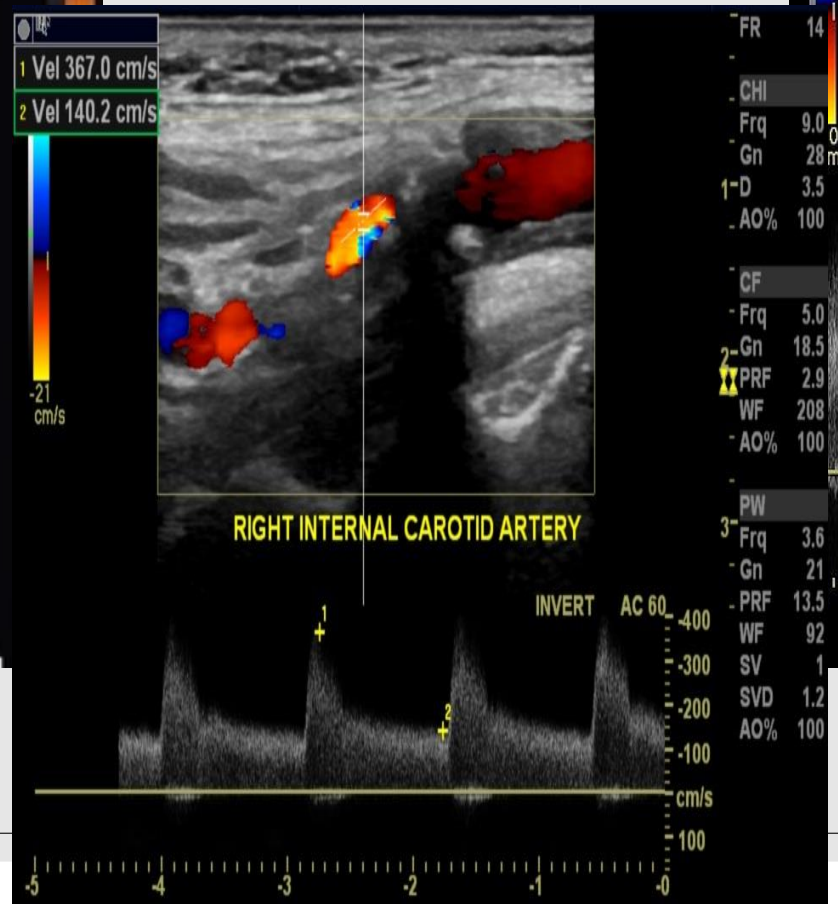


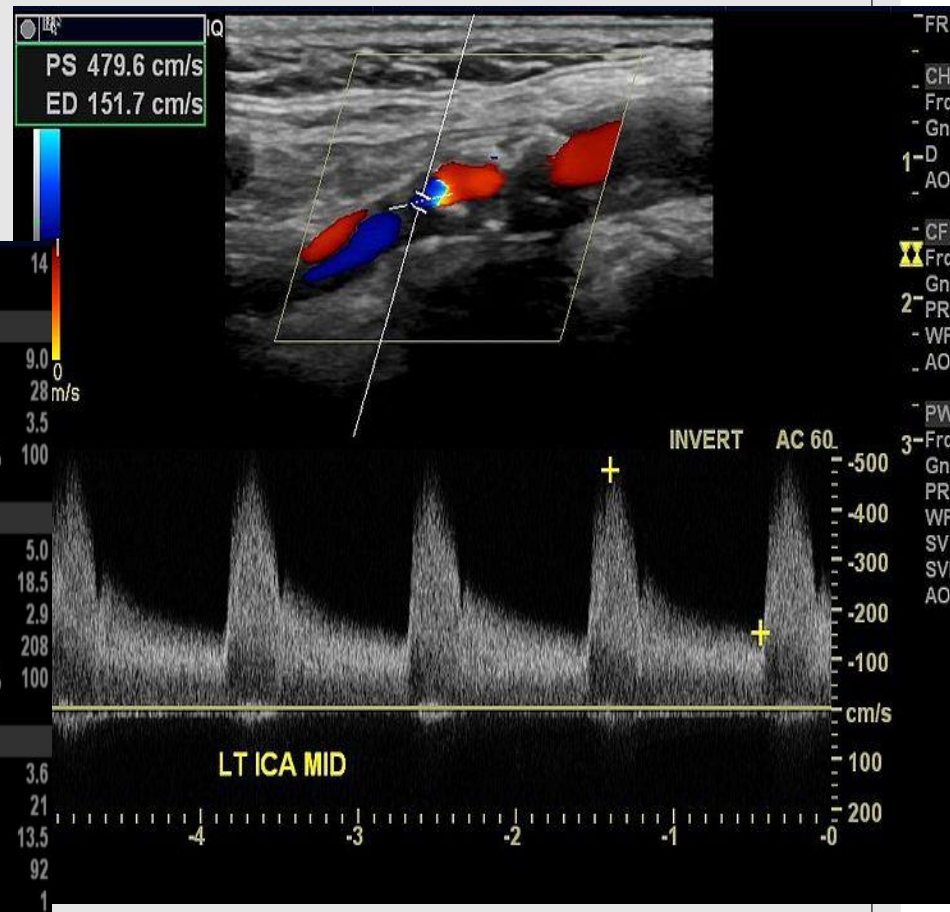
Effects of Stenosis on Flow



Normal

Moderate Stenosis





Severe Stenosis