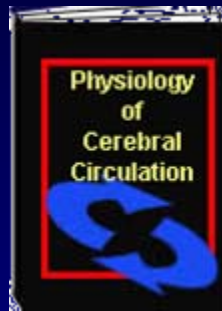




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Physiology Of Cerebral Circulation

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CIRCULATION

FACTORS CONTROLLING BLOOD FLOW

- Intrinsic factors
 - Myogenic Regulation
 - Metabolic Regulation
- Extrinsic factors
 - Neural Regulation
 - Hormonal Regulation

CIRCULATION

- MYOGENIC REGULATION

- Increased blood flow → arterial distension
- Vasoconstriction in response to stretch
- Protective mechanism against excessive pressure fluctuation at capillary level

CIRCULATION

- METABOLIC REGULATION

- \uparrow CO_2

- \uparrow H^+

- \downarrow O_2

- \uparrow K^+

- \uparrow Adenosine

- EDRF / Nitrous Oxide

CIRCULATION

- NEURAL REGULATION
 - α Adrenergic receptors in arterial smooth muscle
 - Postganglionic sympathetic fibers release noradrenaline
 - Causes smooth muscle contraction → Arterial constriction
 - Sympathetic innervation is responsible for vascular tone

CIRCULATION

- HORMONAL REGULATION
 - Adrenaline
 - Vasopressin
 - Angiotensin II

CEREBRAL CIRCULATION

PECULIARITIES OF CNS METABOLISM

- High metabolic rate to supply ionic pumps of neurons
- Low storage of O₂ or Glucose
- Lacks anaerobic metabolism
- Neurons don't require insulin for transport of glucose across cell membrane

CEREBRAL CIRCULATION

PECULIARITIES OF CNS METABOLISM

- ADULT BRAIN
 - 2% of body weight
 - 20% of inspired oxygen consumption at rest
 - 17% of Cardiac output
 - CBF maintained at 55 ml / 100gm / min over a wide range of systemic pressures

CEREBRAL CIRCULATION

- CEREBRAL BLOOD FLOW

- Grey matter 70ml / 100gm / min

- White matter 30ml / 100gm / min

- Mean 55ml / 100gm / min

→ 750 – 900 ml/ min

- OXYGEN CONSUMPTION

- 3.5ml / 100gm / min

- GLUCOSE CONSUMPTION

- 5mg / 100gm / min



CEREBRAL CIRCULATION

- Brain stores of glucose last for 2 min
- Lesser in presence of ischemia
- Brain normally extracts 35% oxygen
- If MAP < 50mm Hg, it can increase oxygen extraction so that ischemia may not occur with MAP as low as 30mm Hg

CEREBRAL CIRCULATION

SAFETY FACTOR

- Normal brain receives
 - 3x required oxygen
 - 7x required glucose
- Safety factor for oxygen < glucose
- Anoxia is the initial component of ischemia.

CEREBRAL CIRCULATION

DETERMINANTS OF CBF - Intrinsic

- AUTOREGULATION (MYOGENIC)
- METABOLIC REGULATION
- NEURAL REGULATION

CEREBRAL CIRCULATION

AUTOREGULATION

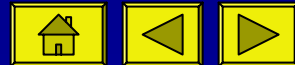
- Definition :

Ability of the cerebral blood vessels to alter their caliber in order to maintain a constant flow in face of variations in blood pressure

CEREBRAL CIRCULATION

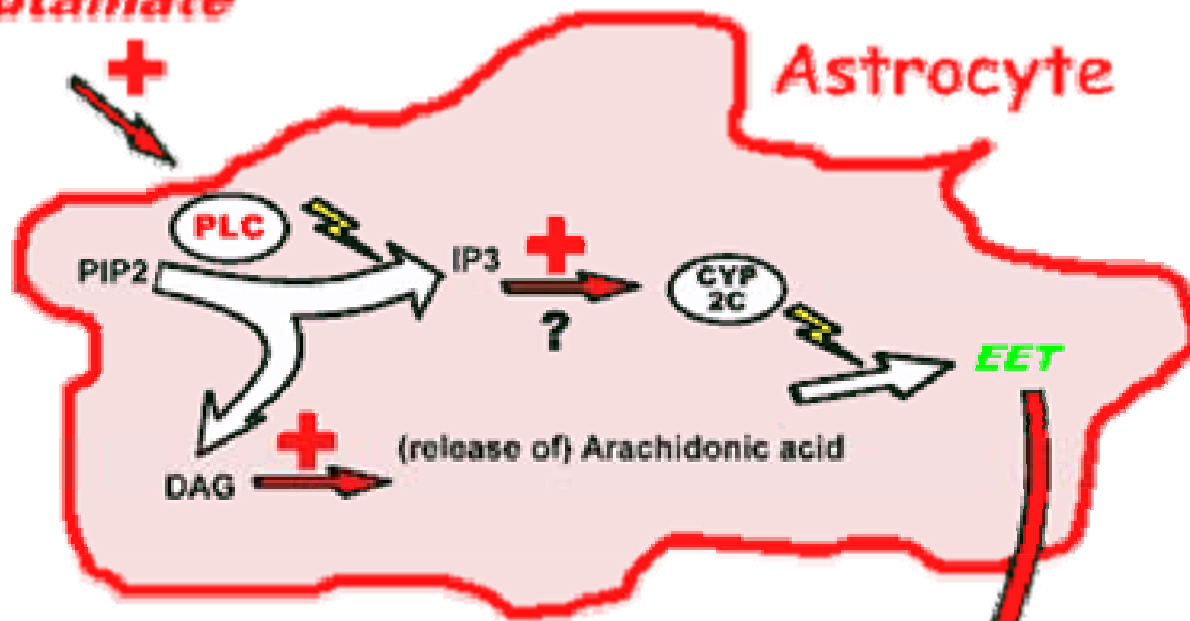
AUTOREGULATION

- CBF is kept constant over a wide range of MAP (50 – 160 mm Hg)
- $CPP = MAP - Ven\ Press = MAP - ICP$
- \uparrow MAP \rightarrow Cerebral vasoconstriction
- \downarrow MAP \rightarrow Cerebral vasodilatation

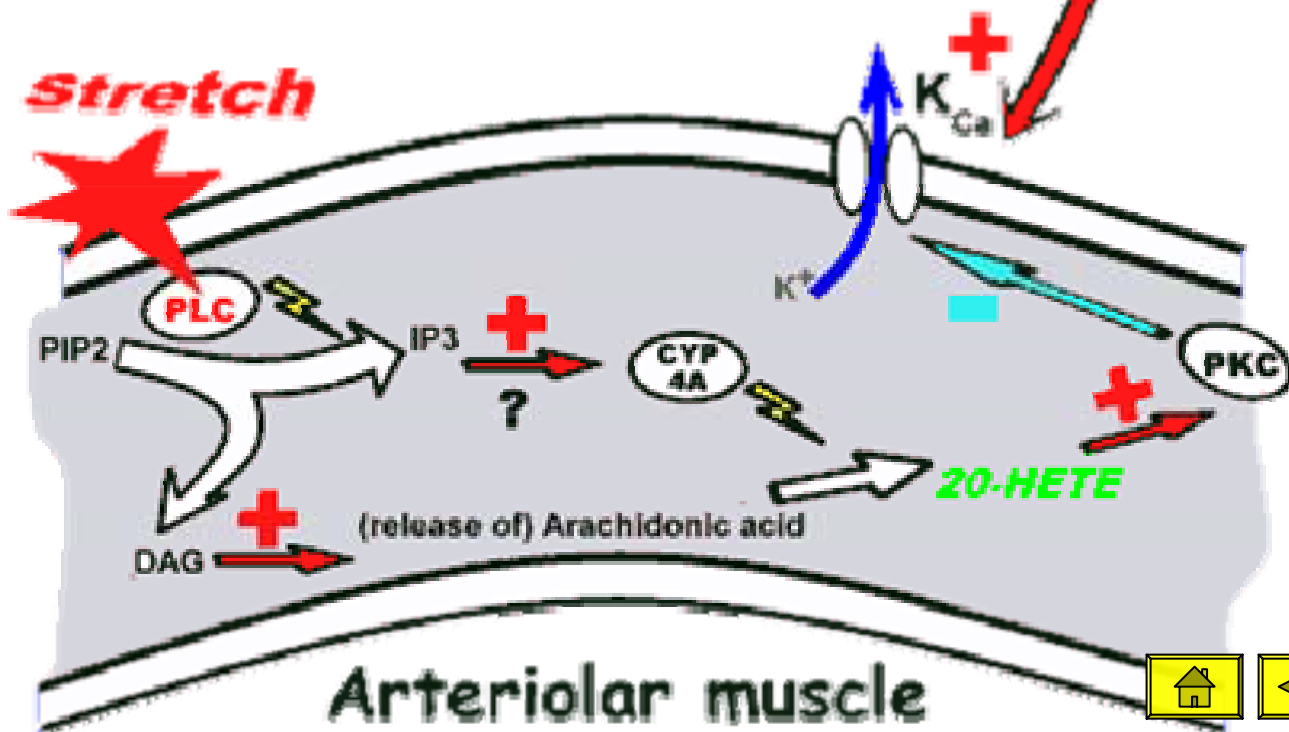


Constant CBF

glutamate



Stretch



CBF (ml/100g/min)

CBF₁

CBF₂

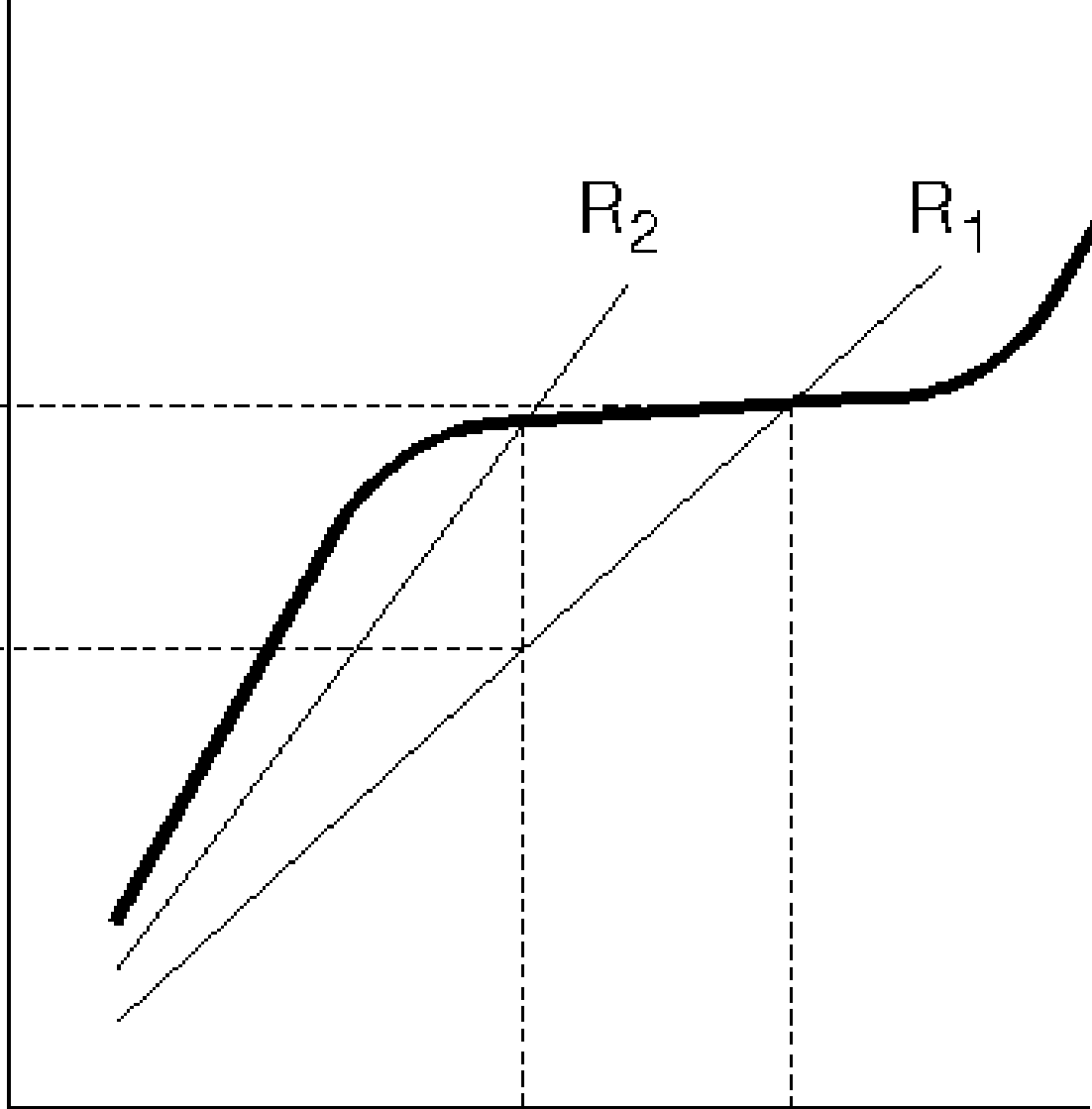
R₂

R₁

CPP₂

CPP₁

CPP (mmHg)



CEREBRAL CIRCULATION

AUTOREGULATION

- Autoregulatory changes take time
 - Up to 60 sec
 - Large MAP changes may cause increased CBF even in presence of intact autoregulation
- In Hypertensive persons
 - Autoregulatory range shifts to higher pressure levels : 180 – 200mm Hg

CEREBRAL CIRCULATION

AUTOREGULATION

- Absent (Vasomotor paralysis)
 - brain trauma
 - surgical retraction
 - high ICP
 - brain tumor
 - seizures
- Shift to right
 - Systemic hypertension
 - States of sympathetic activation
- Shift to left
 - Volatile anesthetic agents

CEREBRAL CIRCULATION

METABOLIC CONTROL

- $\downarrow O_2 \rightarrow$ Vasodilatation
- $\uparrow H^+ \rightarrow$ Vasoconstriction
 - $\uparrow CO_2$
 - Lactic acid $\rightarrow H^+$

CEREBRAL CIRCULATION

METABOLIC CONTROL : HYPOXIA

- Cerebral vasodilatation begins at tissue pO_2 of 35 – 40mm Hg
- If MAP < 50mm Hg, oxygen extraction increases so that ischemia may not occur with MAP as low as 30mm Hg
- Response is very poor



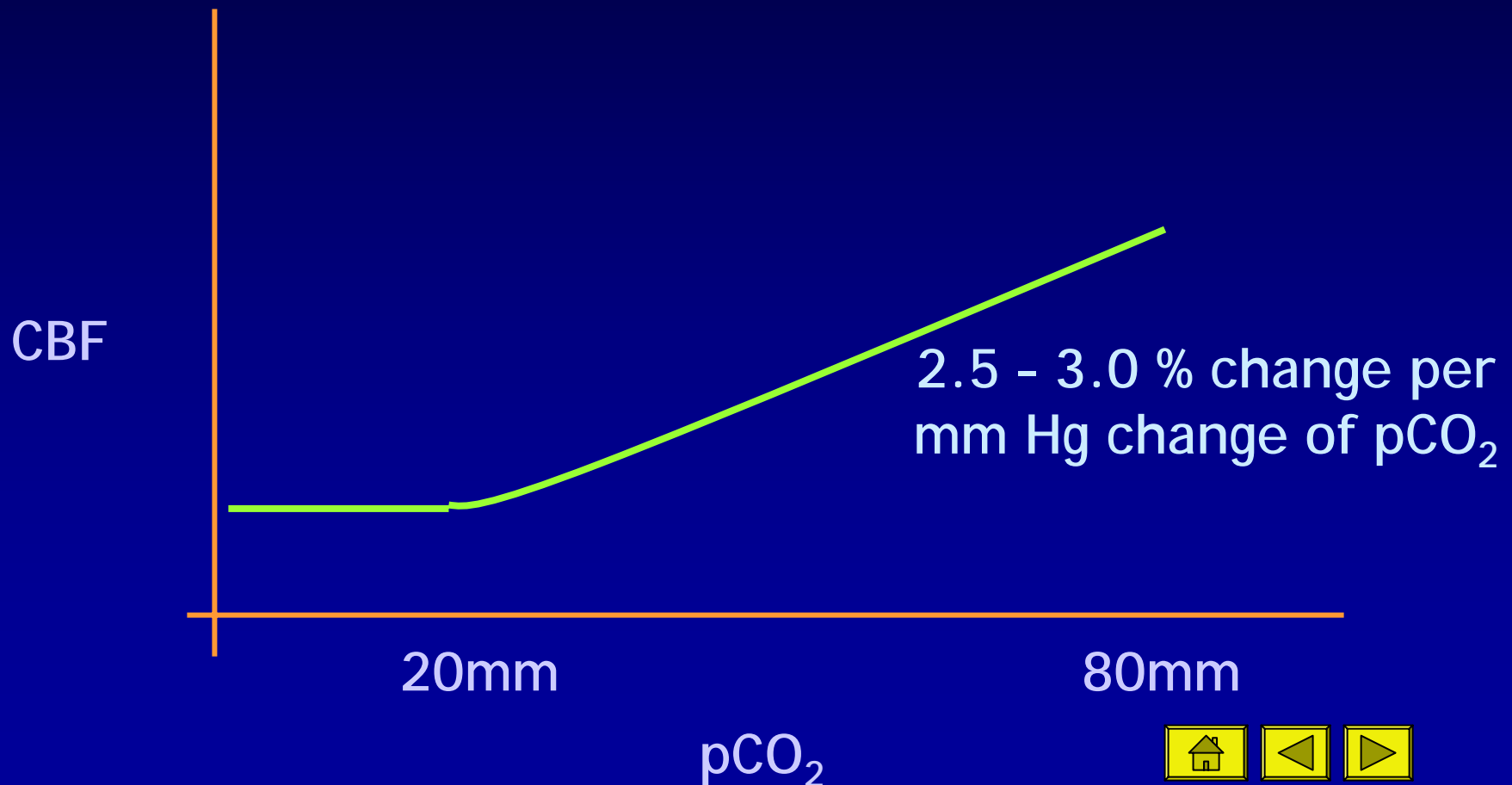
CEREBRAL CIRCULATION

METABOLIC CONTROL : HYPERCARBIA

- Vasodilatation of minor arteries approaching the capillary bed
- Such alterations take precedence over autoregulatory mechanisms
- Very potent vasodilator mechanism

CEREBRAL CIRCULATION

METABOLIC CONTROL : HYPERCARBIA



CEREBRAL CIRCULATION

METABOLIC CONTROL : HYPERCARBIA

- 70% increase in $p\text{CO}_2$ \rightarrow 100% increase in CBF
- $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+$

CEREBRAL CIRCULATION

METABOLIC CONTROL : H^+ ION CONC.

- $\uparrow H^+$ depresses neuronal activity
- Dilatation is almost proportional to increase in hydrogen ion concentration up to CBF of twice normal
- Also other metabolic acids
 - Lactic acid
 - Pyruvic acid
 - Others



CEREBRAL CIRCULATION

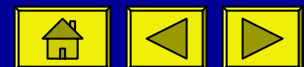
NEURAL REGULATION

- NEUROTRANSMITTERS
 - Serotonin
 - Others
- SYMPATHETIC
 - Cervical sympathetic outflow

CEREBRAL CIRCULATION

NEURAL REGULATION – Sympathetic System

- Large & Medium sized arteries
- Normally overridden by autoregulation
- Historically thought to have no role in cerebral circulation
- Comes into play in states of excessive circulatory activity
- Role in prevention of cerebral h'ge.



CEREBRAL CIRCULATION

DETERMINANTS OF CBF - Extrinsic

- ARTERIAL BP
- HEMATOCRIT

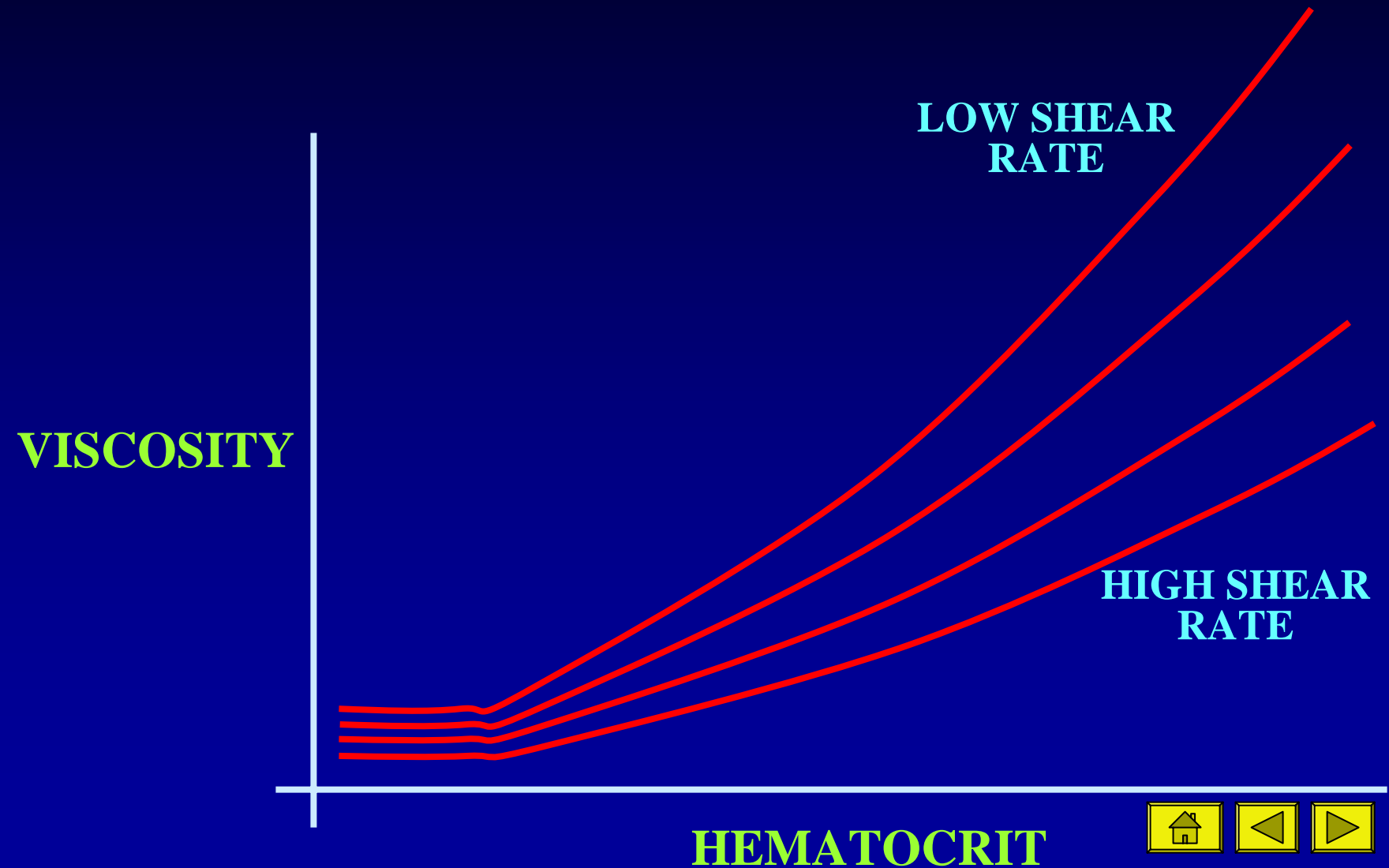
CEREBRAL CIRCULATION

HEMATOCRIT

- FLOW IN A VESSEL
 - Hagen Poisuelle equation

$$Q = \frac{\Delta P \pi r^4}{8 L \eta}$$

CEREBRAL CIRCULATION



pressure regulation

DYNAMIC PRESSURE-
FLOW RELATIONSHIP

CBF

VASCULAR
SMOOTH
MUSCLE

BALANCE
BETWEEN
SUPPLY
AND
DEMAND

external
chemical

neurogenic
regulation

metabolic regulation



CEREBRAL CIRCULATION

Applied Aspects



CEREBRAL CIRCULATION

ANGIOGRAPHY PHASES :

- Arterial phase
- Intermediate / Capillary / Mixed phase
- Venous phase

CEREBRAL CIRCULATION

ARTERIAL PHASE :

- 1 – 2.5 sec (Mean: 1.5sec)
- Injection time is to be controlled
- Prolonged arterial phase only if injection time is not prolonged

CEREBRAL CIRCULATION

ARTERIAL CIRCULATION TIME :

- Time from maximal concentration of contrast medium in
 - Carotid siphon
 - Terminal branches of arteries
- Regional variation
 - Length of arteries
 - Gravity
 - Cortical activity

CEREBRAL CIRCULATION

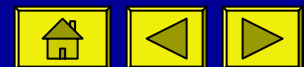
ARTERIAL CIRCULATION TIME :

- Frontal - 1.0 sec
- Insular - 1.25 sec
- Parietooccipital - 1.25 sec
- Parietal - 1.5 sec

CEREBRAL CIRCULATION

INTERMEDIATE / MIXED / CAPILLARY PHASE :

- Not well defined
- Only terminal branches of arteries and small frontal vein origins are opacified
- Duration : 0.5 – 1.0 sec
- May be completely absent



CEREBRAL CIRCULATION

VENOUS PHASE :

- Time from opacification of first branches of superficial cerebral veins to complete washout of contrast
- Duration : 4 – 5 sec
- Highly dependent on quantity of contrast used and speed of injection

CEREBRAL CIRCULATION

VENOUS PHASE :

- Frontal Vv opacified before parietal
- Deep veins fill after superficial veins
- Simultaneous filling in 20%
- Earlier filling of deep veins in 4 – 8%

CEREBRAL CIRCULATION

ANGIOGRAPHIC (AV) CIRCULATION TIME :

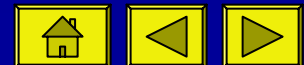
- Time from maximal concentration of the contrast in
 - Carotid siphon
 - Parietal veins
- Mean : 4.13 sec
- Prolonged if > 6 sec

CEREBRAL CIRCULATION

INTRACRANIAL ANEURYSMS

- ANEURYSMS:

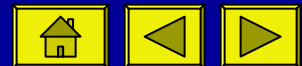
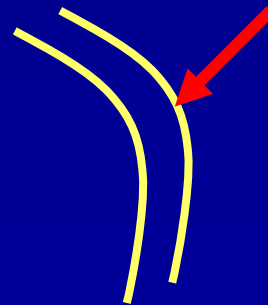
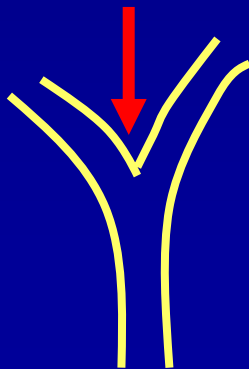
- Saccular - Degenerative changes in the vessel wall due to hemodynamic stresses
- Other causes
- Fusiform - Atherosclerosis
- Dissecting - Spontaneous / Trauma



CEREBRAL CIRCULATION

SACCULAR ANEURYSMS

- Arise at points of maximal mechanical shear stresses
 - Bifurcations
 - Lateral wall of curved artery
 - At sites of Duplications / Fenestrations



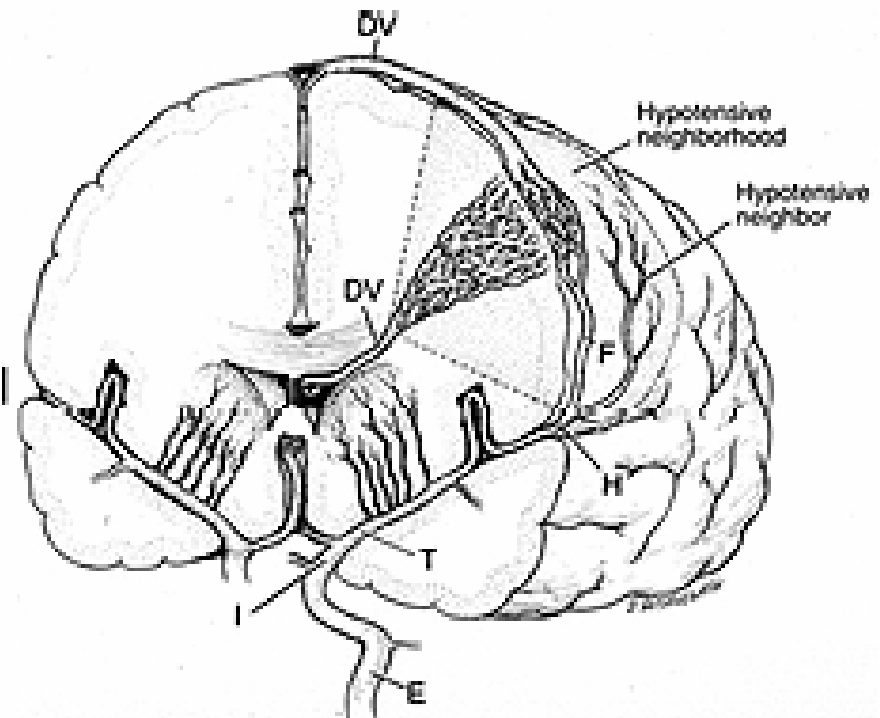
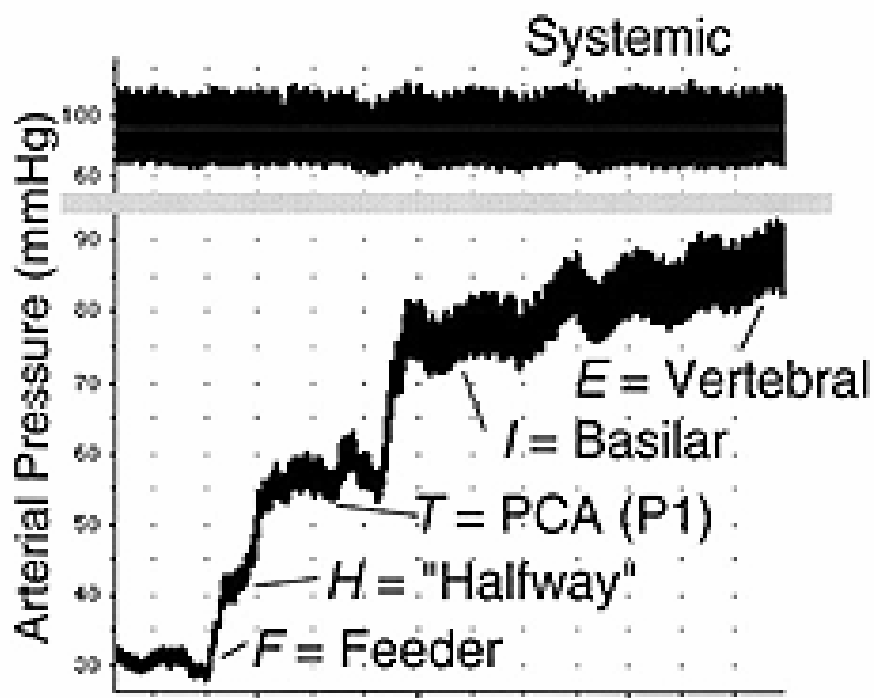
CEREBRAL CIRCULATION

AV MALFORMATIONS

- CAUSE :
 - High flow across AV shunt
 - Hypotension along the path of shunt
 - Circulatory beds in parallel with the shunt are perfused at low pressure (though flow is normal)

CEREBRAL CIRCULATION

AV MALFORMATIONS



CEREBRAL CIRCULATION

AV MALFORMATIONS

- TERRITORIES ADJACENT TO SHUNT
 - Shift of autoregulation to left
 - Preservation of CO₂ responsiveness
- WHOLE BRAIN
 - Change in total cerebrovascular resistance

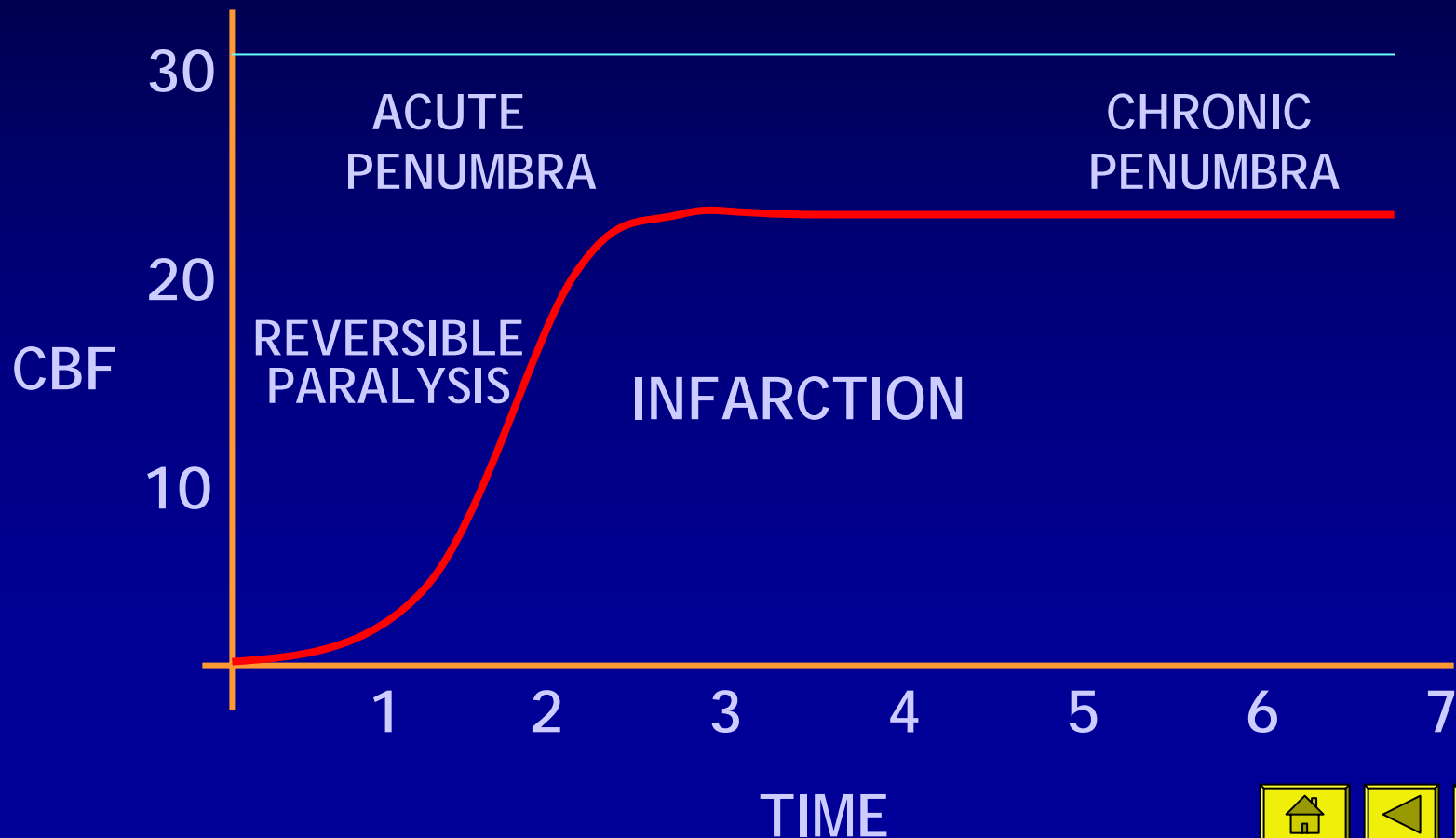
CEREBRAL CIRCULATION

CEREBRAL ISCHEMIA

- CBF 40 - 60ml / 100gm / min
 - Normal
- CBF 20 – 30ml / 100gm / min
 - Start of neurological symptoms
- CBF 16 – 20 ml / 100gm / min
 - Isoelectrical EEG, Loss of evoked potentials
- CBF 10 – 12ml / 100gm / min
 - Na / K pump failure, Cytotoxic edema
- CBF < 10ml / 100gm / min
 - Irreversible brain damage \propto ischemic time

CEREBRAL CIRCULATION

CEREBRAL ISCHEMIA



CEREBRAL CIRCULATION

HYPERTENSIVE ENCEPHALOPATHY

- Failure of autoregulation
- Dilatation of large and medium sized arteries
- Excessive vasoconstriction of small arteries ($<200\mu$)
- Infarcts, Failure of BBB, petechiae
- Fibrinoid arterial necrosis



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