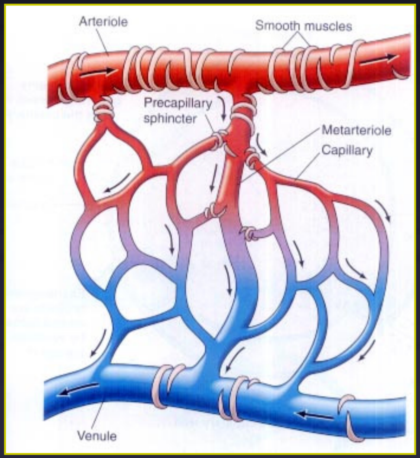
Autoregulation of cerebal blood flow



DR SYED SHAHID HABIB
MBBS DSDM FCPS
Professor & Consultant Clinical Neurophysiology
Dept. of Physiology
College of Medicine & KKUH

OBJECTIVES

At the end of this lecture you should be able to

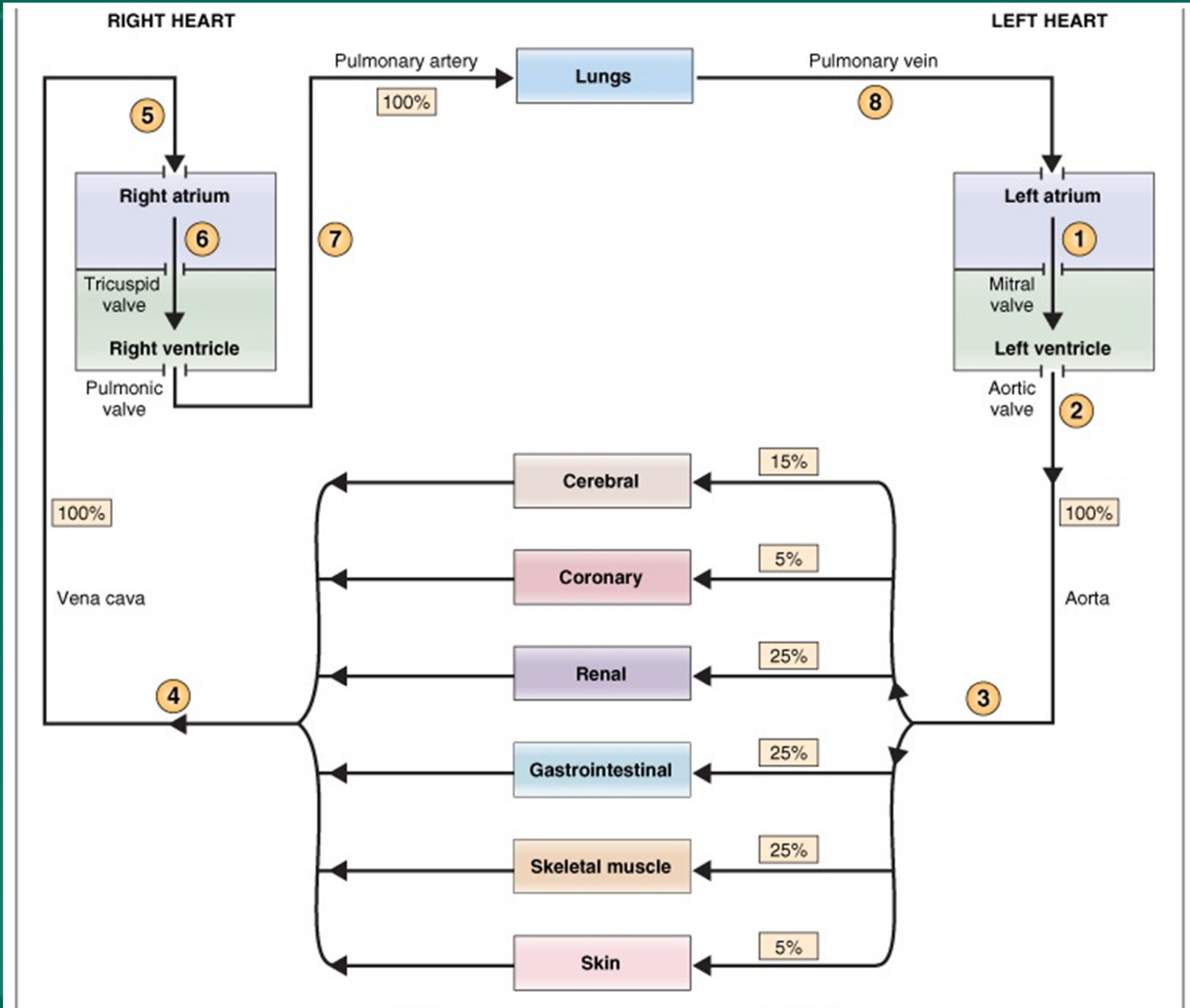
- Describe cerebral circulation & circle of Willis
- Enumarate main arteries that supply blood to brain
- Normal characteristics of Cerebral Blood Flow
- Explain auto-regulation of cerebral blood flow
- Explain the factors effecting the cerebral blood flow
- Understand cerebral stroke & its effects

INTRODUCTION

- Most vital organ
- Containing centers for circulation , respiration and most other bodily functions
- Needs continues blood supply
- Highly sensitive to hypoxia
- Uses glucose as main fuel
- Metabolic requirements are fairly constant irrespective of needs

FACTS ABOUT BLOOD SUPPLY OF BRAIN

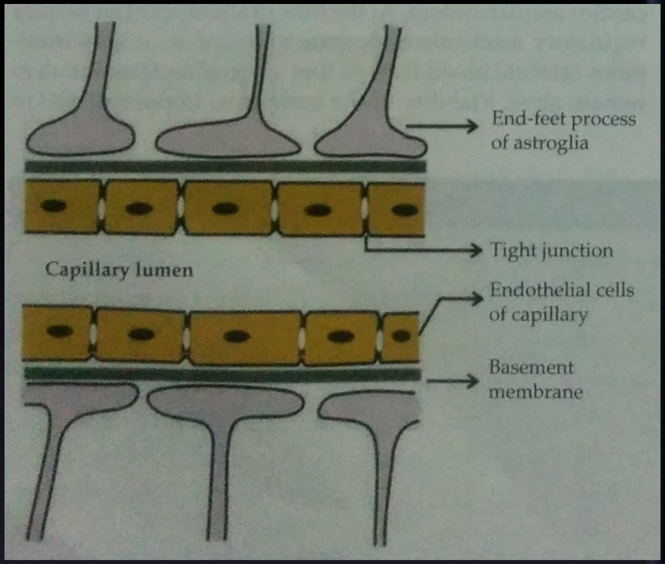
- Brain - 2% of body weight (Wt of brain is 1400g)
- Receives - 15% of cardiac output (750-900 ml per min, 50-65 ml/100g tissue /min)
- Consumes - 20% of entire Oxygen used by the body (3.3ml of O_2/100g/min)
- 10 seconds of interruption in blood flow leads to unconsciousness
- Most neurologic disorders are due to vascular lesions
- Can be measured by radioactive xenon injection into carotid arteries



RIGHT HEART
LEFT HEART
Pulmonary artery
100%
Lungs
Pulmonary vein
5
8
Right atrium
6
7
Left atrium
1
Tricuspid valve
Mitral valve
Right ventricle
Left ventricle
Pulmonic valve
Aortic valve
2
15%
Cerebral
100%
100%
5%
Coronary
Vena cava
Aorta
25%
Renal
4
3
25%
Gastrointestinal
25%
Skeletal muscle
5%
Skin

Special Features

- Cerebral arteries are end arteries
- Volume of blood , ECF , CSF remains fairly constant
- Capillaries in brain are mostly non-fenestrated
- Capillaries are surrounded by foot process of astrocytes
- Form blood brain barrier



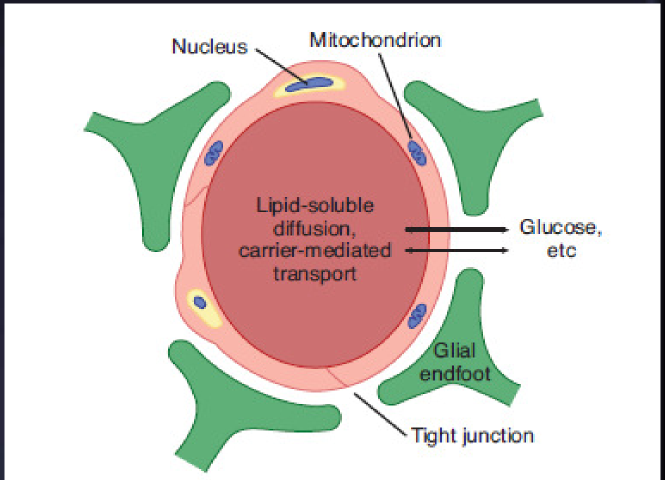


FIGURE 34–2 Transport across cerebral capillaries.

Cerebral Microcirculation

- brain capillaries are surrounded by the endfeet of astrocytes
- closely applied to the basal lamina of the capillaries,
- do not cover the entire capillary wall
- gaps of about 20 nm occur between endfeet
- induce the tight junctions in the capillaries

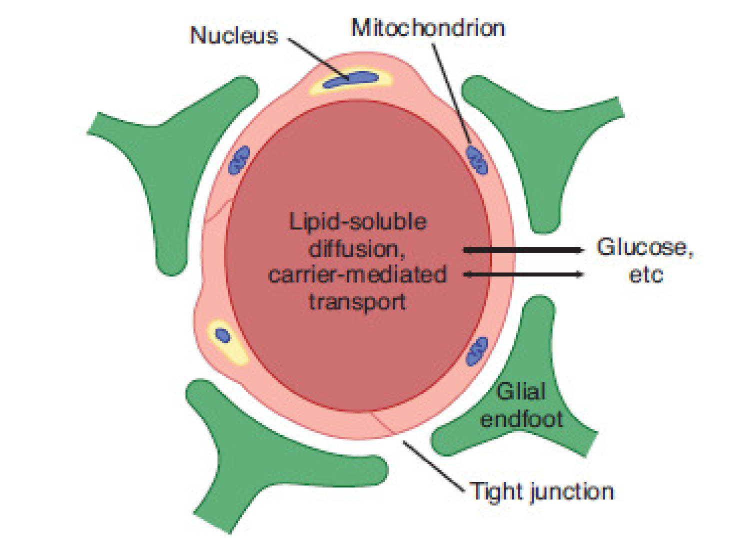


FIGURE 34–2 Transport across cerebral capillaries.

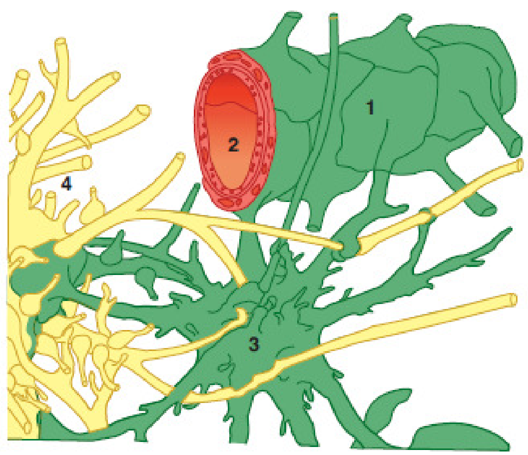


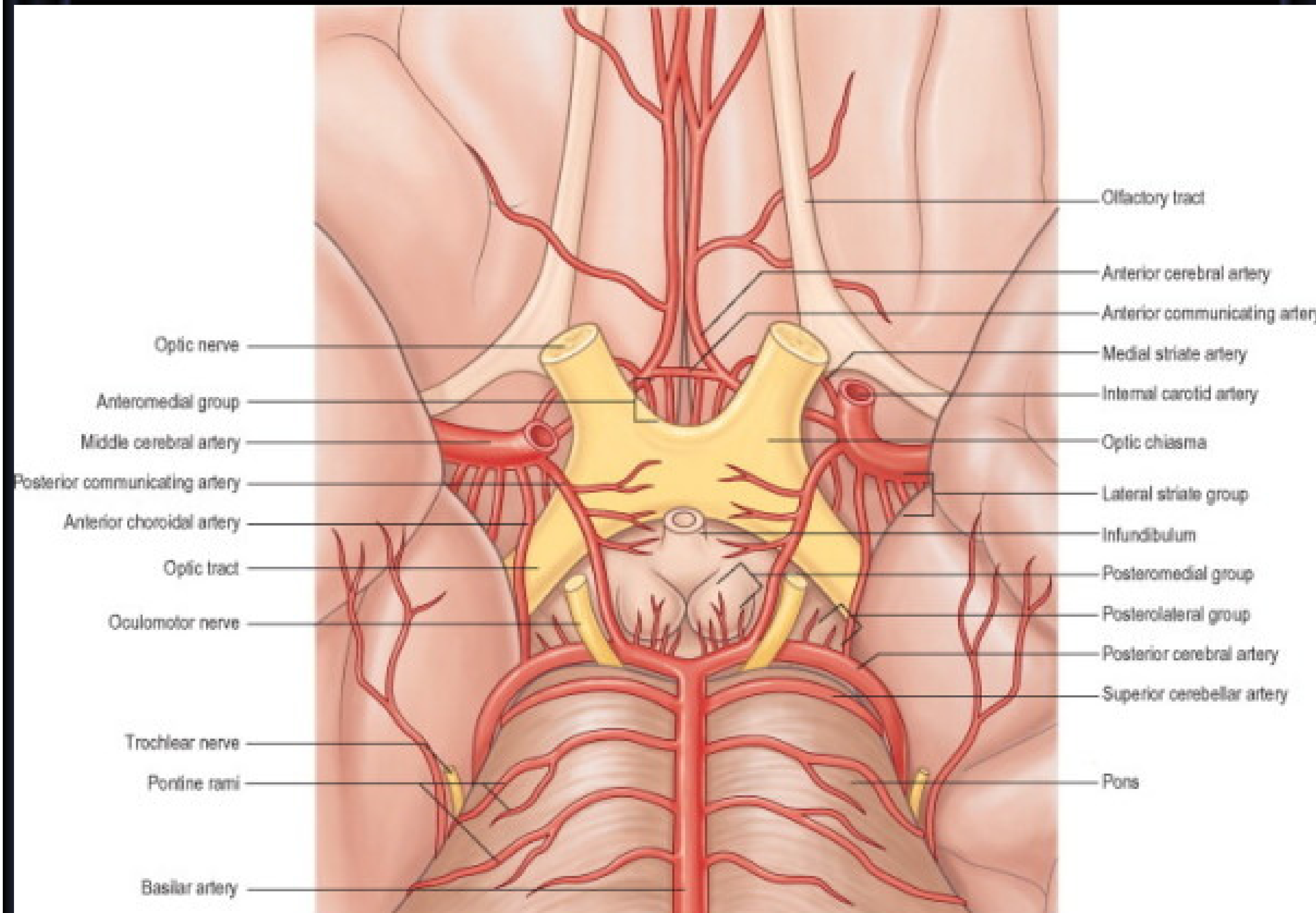
FIGURE 34–1 Relation of fibrous astrocyte (3) to a capillary (2) and neuron (4) in the brain. The endfeet of the astrocyte processes form a discontinuous membrane around the capillary (1). Astrocyte processes also envelop the neuron. (Adapted from Krstic RV: *Die Gewebe des Menschen und der Säugetiere.* Springer, 1978.)

The number of blood capillaries in brain is greatest where metabolic needs are greatest (metabolic rate of brain gray matter is 4 times greater and so is number of capillaries)

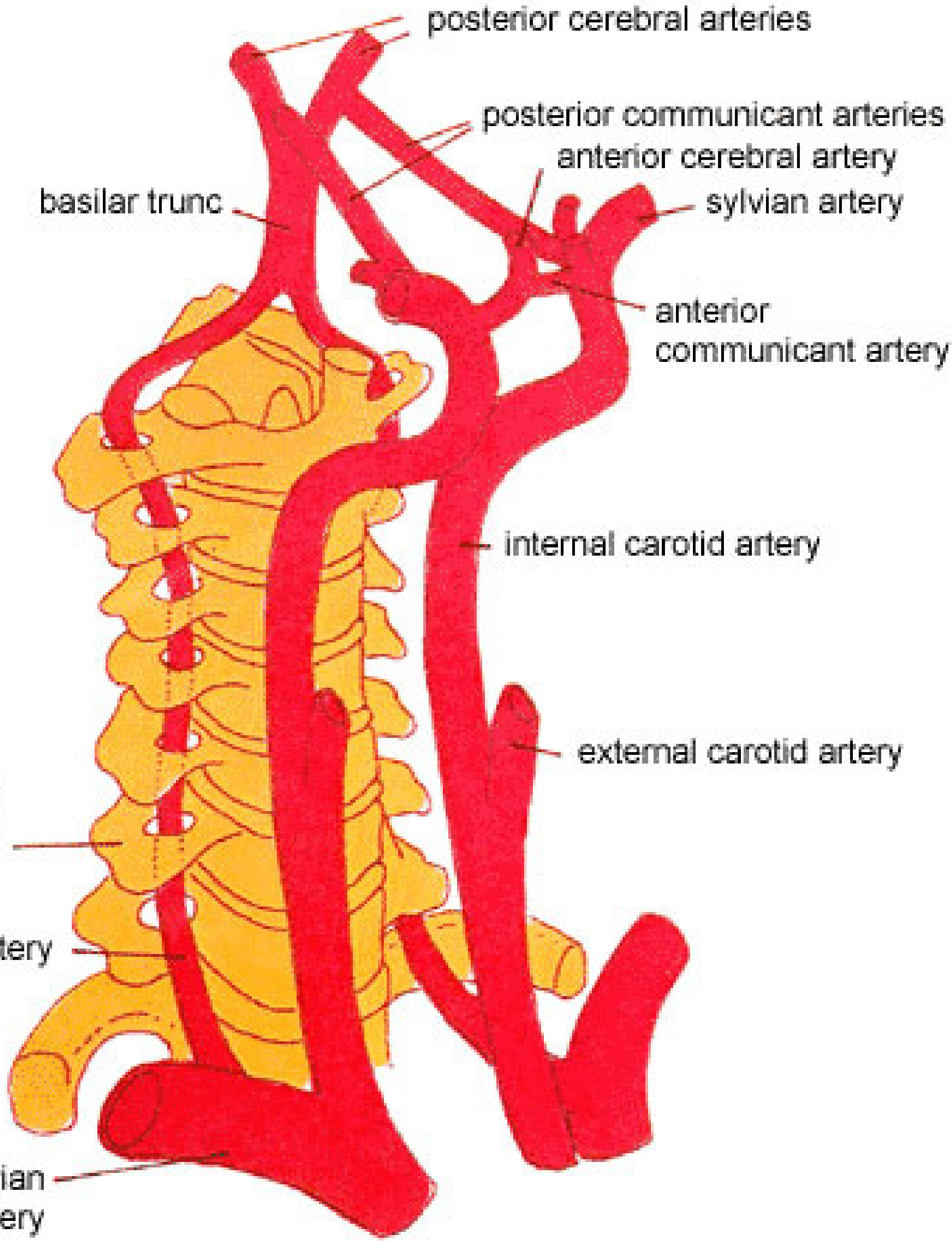
Cerebral Blood Vessels

- Receives blood from two major sources
  1. Vertebro-basilar system
  2. Internal carotid arteries
- Both systems unite to form circle of willis
- Which give rise to three pairs of major vessels
  - Anterior cerebral arteries
  - Middle cerebral arteries
  - Posterior cerebral arteries

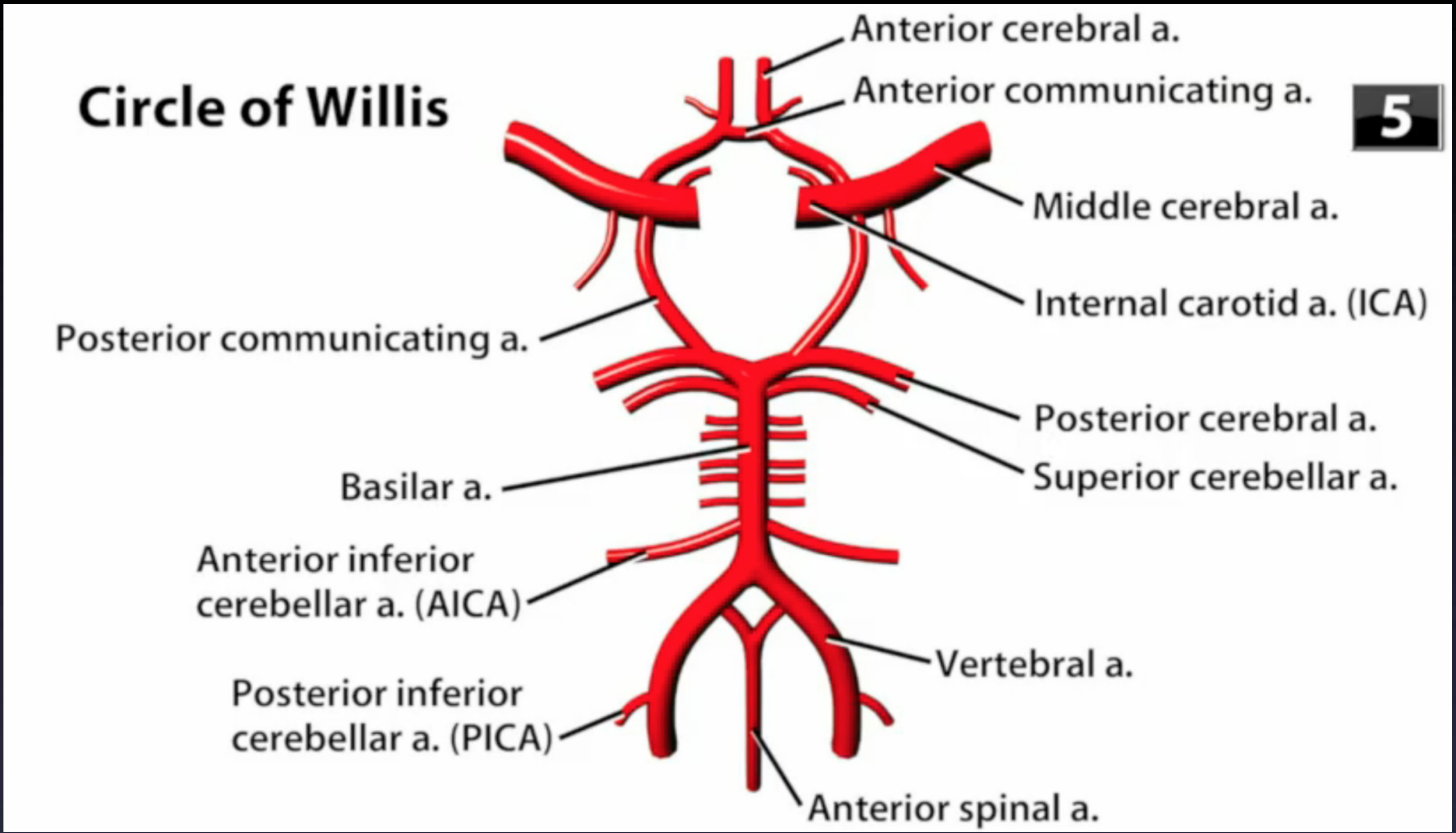
•Carotid artery contributes approximately 80% to the total cerebral blood flow, the remaining 20% from the two vertebral arteries



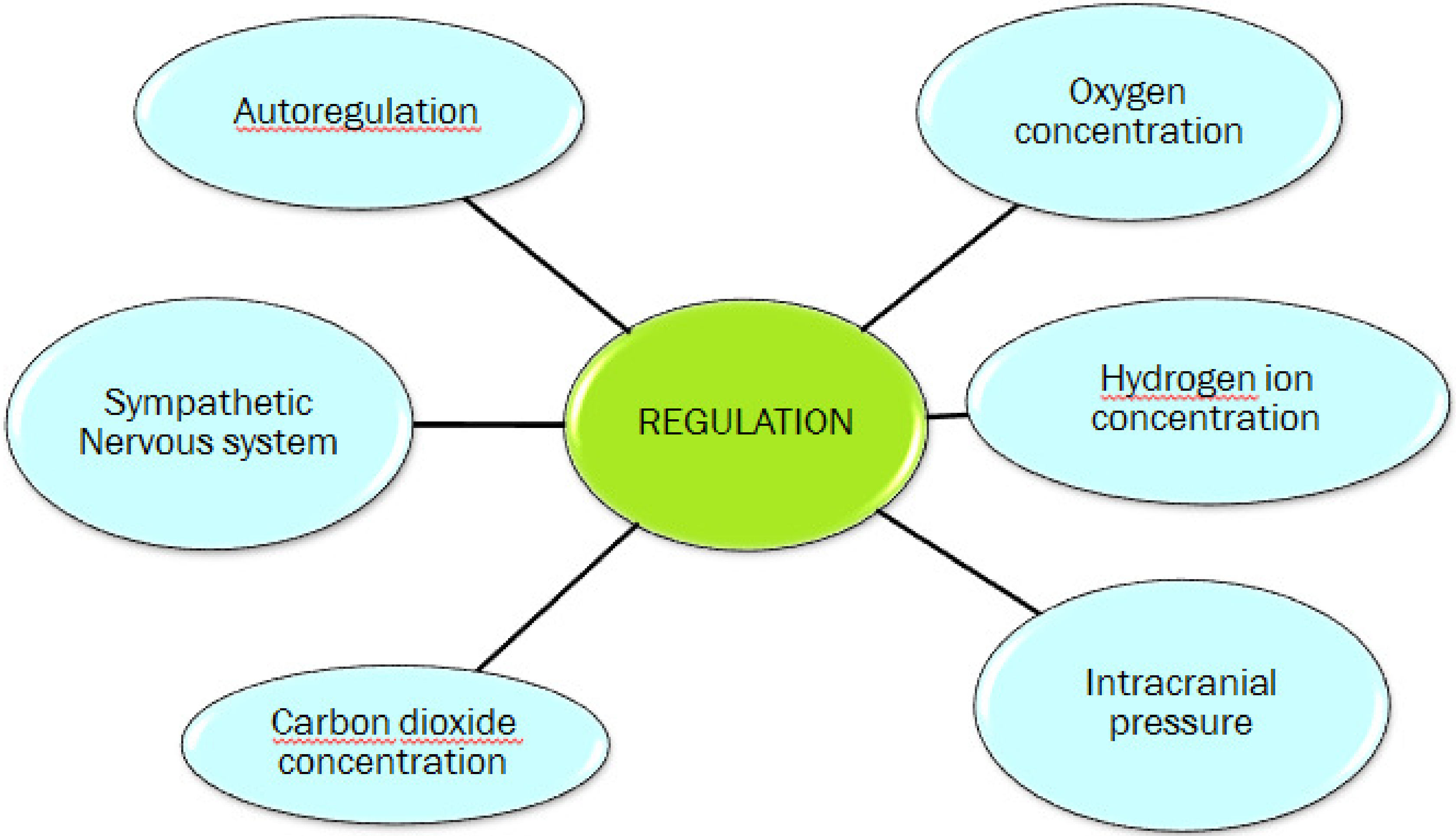
Olfactory tract
Anterior cerebral artery
Anterior communicating artery
Medial striate artery
Internal carotid artery
Optic chiasma
Lateral striate group
Infundibulum
Posteromedial group
Posterolateral group
Posterior cerebral artery
Superior cerebellar artery
Pons
Optic nerve
Anteromedial group
Middle cerebral artery
Posterior communicating artery
Anterior choroidal artery
Optic tract
Oculomotor nerve
Trochlear nerve
Pontine rami
Basilar artery


posterior cerebral arteries
posterior communicant arteries
anterior cerebral artery
basilar trunc
sylvian artery
anterior
communicant artery
internal carotid artery
external carotid artery
6th cervical
vertebra
vertebral artery
subclavian
artery

Circle Of Wilis



Regulation of Cerebral Blood Flow



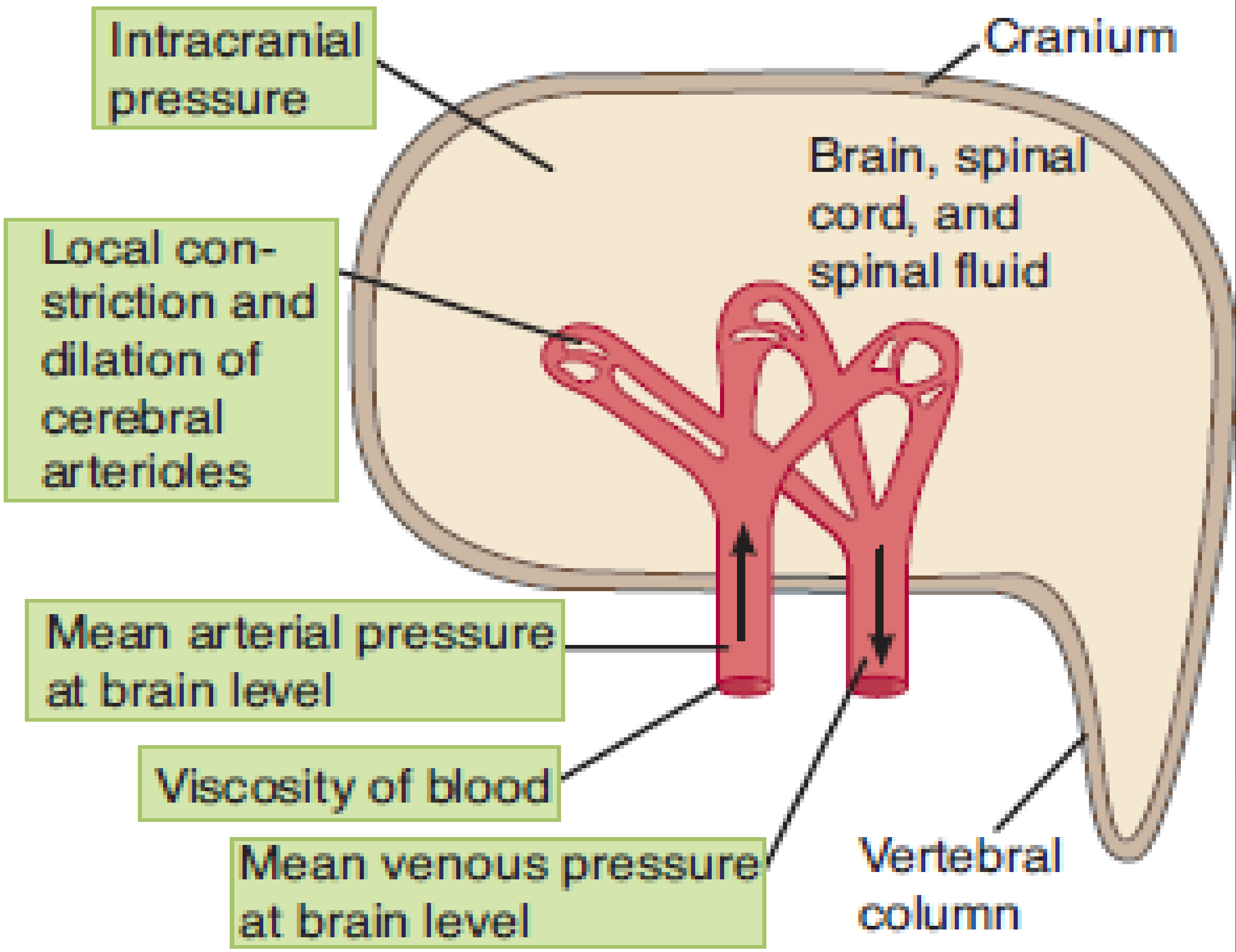


FIGURE 34–8 Diagrammatic summary of the factors affecting overall cerebral blood flow.

Regulation of Cerebral Blood Flow by metabolic factors

Metabolism of the tissue. At least three metabolic factors have potent effects in controlling cerebral blood flow:

(1) carbon dioxide concentration,

(2) hydrogen ion concentration

(3) oxygen concentration.

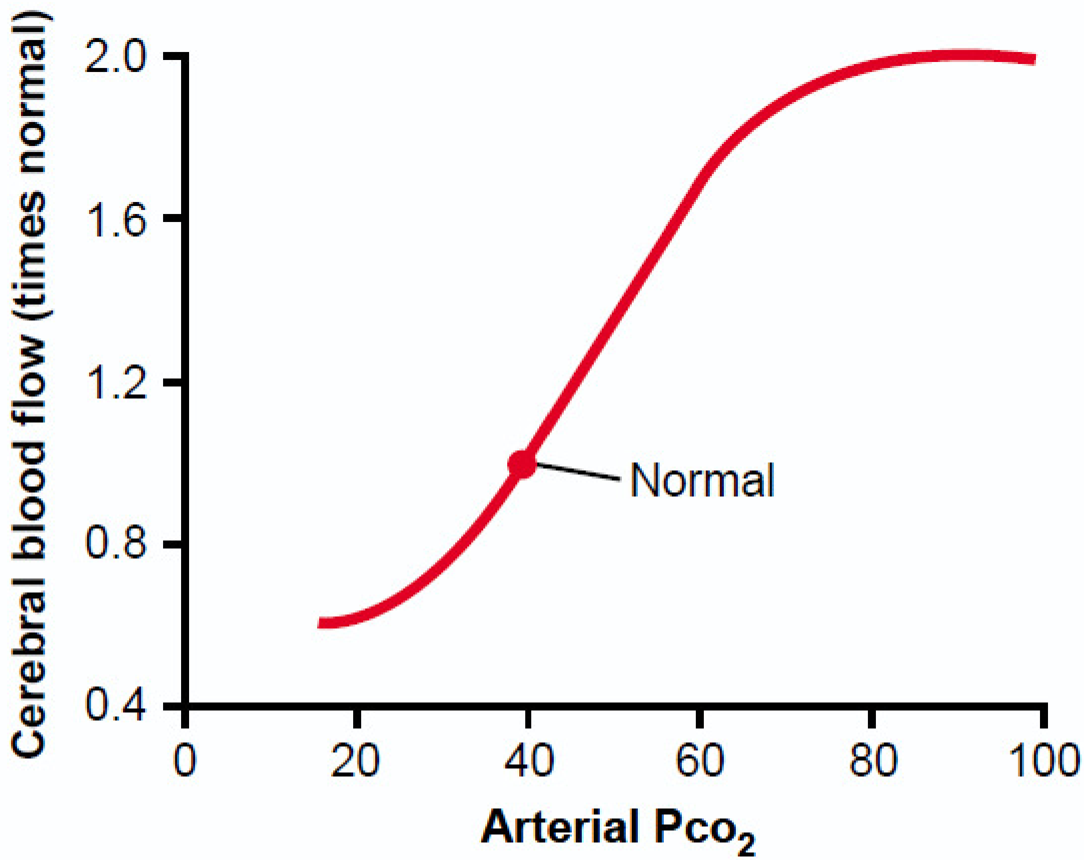


Figure 61–1

Relationship between arterial P_{CO_2} and cerebral blood flow.

Effect of local neuronal activity on Cerebral blood flow,

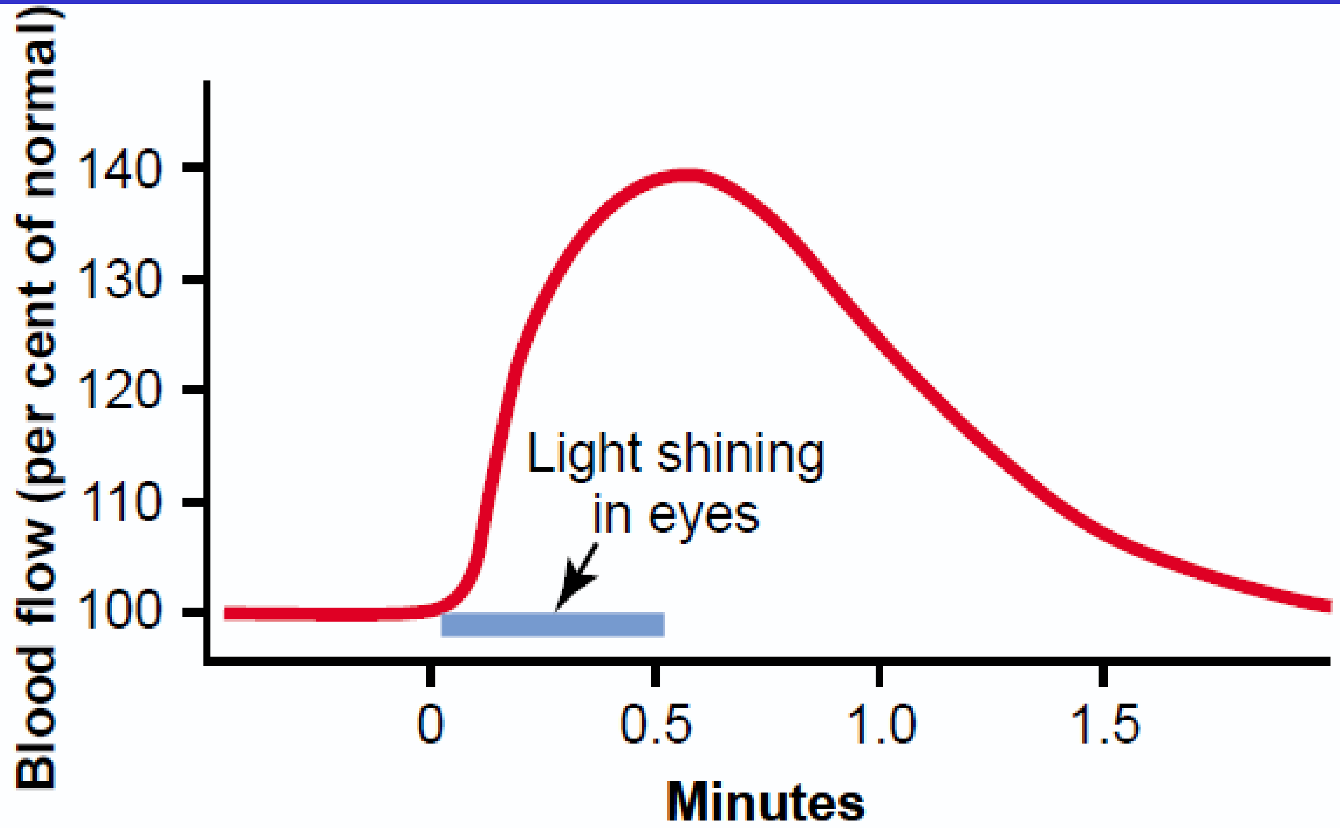


Figure 61–2

Increase in blood flow to the occipital regions of a cat's brain when light is shined into its eyes.

Autoregulation of Cerebral Blood Flow When the Arterial Pressure Changes.

- Cerebral blood flow is "autoregulated" extremely well between arterial pressure limits of 60 and 140 mm Hg.
- That is, mean arterial pressure can be decreased acutely to as low as 60 mm Hg or increased to as high as 140 mm Hg without significant change in cerebral blood flow.
- In people who have hypertension, autoregulation of cerebral blood flow occurs even when the mean arterial pressure rises to as high as 160 to 180 mm Hg

Controlled almost entirely by local metabolites

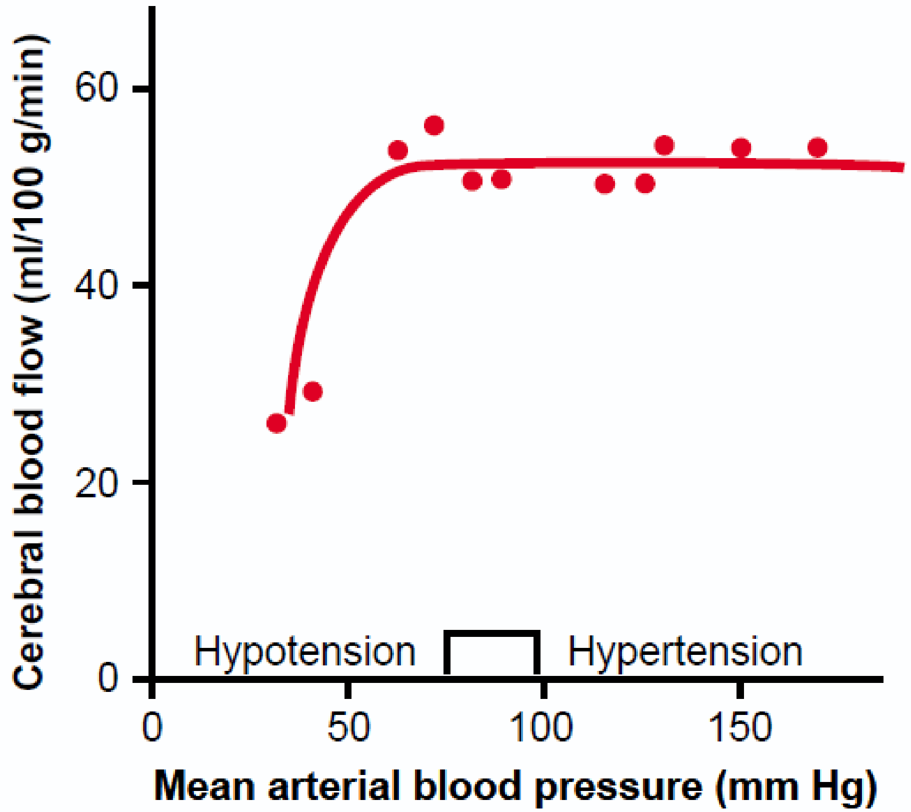


Figure 61–3

Effect of differences in mean arterial pressure, from hypotensive to hypertensive level, on cerebral blood flow in different human beings. (Modified from Lassen NA: Cerebral blood flow and oxygen consumption in man. Physiol Rev 39:183, 1959.)

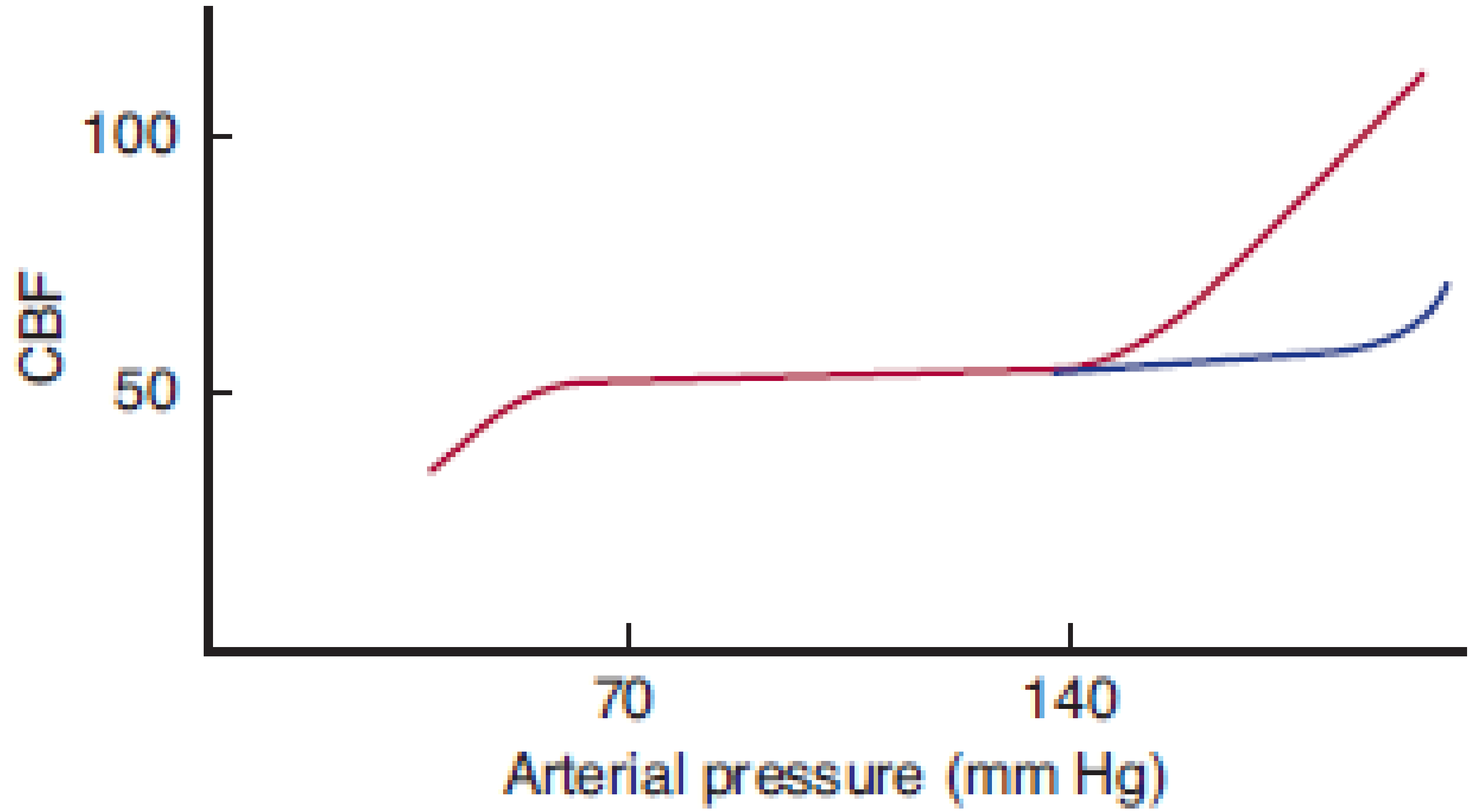


FIGURE 34–9 Autoregulation of cerebral blood flow (CBF) during steady-state conditions. The blue line shows the alteration produced by sympathetic stimulation during autoregulation.

Role of the Sympathetic Nervous System in Controlling Cerebral Blood Flow.

- The cerebral circulatory system has strong sympathetic innervation that passes upward from the superior cervical sympathetic ganglia in the neck and then into the brain along with the cerebral arteries.
- This innervation supplies both the large brain arteries and the arteries that penetrate into the substance of the brain.
- However, transection of the sympathetic nerves or mild to moderate stimulation of them usually causes very little change in cerebral blood flow because the blood flow autoregulation mechanism can override the nervous effects.

During strenuous exercise or states of excessive circulatory activity, the sympathetic nervous system normally constricts the large- and intermediate-sized brain arteries enough to prevent the high pressure from reaching the smaller brain blood vessels to prevent stroke

INTRACRANIAL PRESSURE (ICP) & CEREBRAL BLOOD FLOW

- Intracranial pressure(ICP) rise (normal 0-10 mmHg) → Cerebral vessels compressed
- Change in venous pressure → a similar change in ICP
- Rise in venous pressure decreases cerebral blood flow by
  - decreasing the effective perfusion pressure
  - compressing the cerebral vessels

Monro–Kellie doctrine: States that volume of brain tissue , CSF , blood in vessels are in equilibrium and remain constant inside rigid cranial cavity

CARBON DIOXIDE & HYDROGEN CONCENTRATION

- most important local vasodilators
  - ↑ in cerebral Pco2
  - formation of carbonic acid →dissociation → H+
  - ↑ in H+ concentration = ↓ in pH
  - causes vasodilation of the cerebral arterioles
  - results in an ↑ in blood flow to remove the excess CO2.

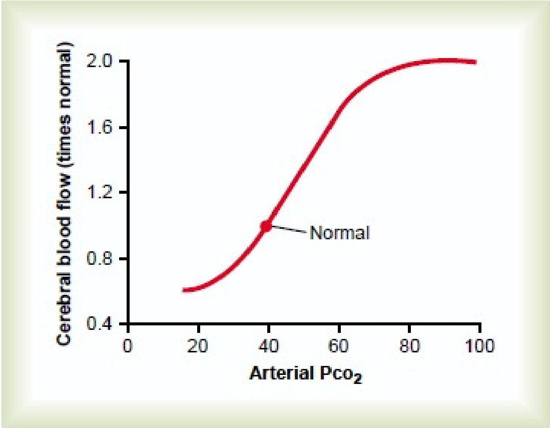
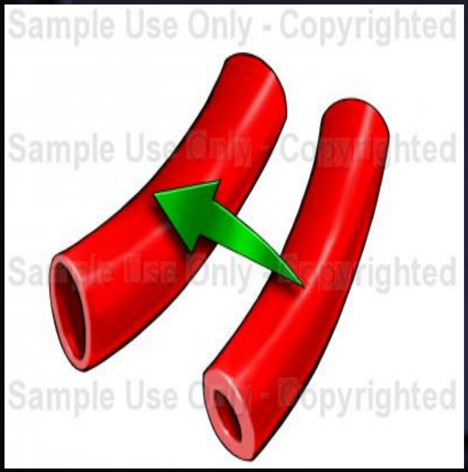


Figure 61–1

Relationship between arterial P_{CO_2} and cerebral blood flow.



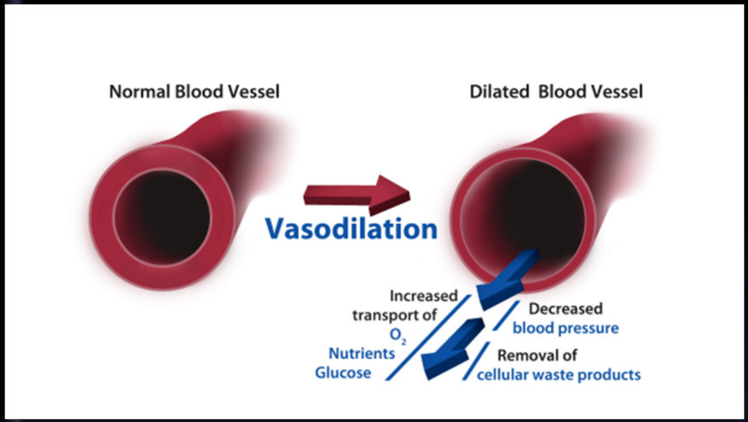
- **Any other substance that ↑ the acidity of the brain tissue**
  → ↑ hydrogen ion concentration
  → ↑ cerebral blood flow
  - **lactic acid**
  - **pyruvic acid**
  - **other acidic material formed during the course of tissue metabolism.**

IMPORTANCE

↑ hydrogen ion concentration greatly depresses neuronal activity.

- By ↑ the blood flow
  - Remove hydrogen ions, carbon dioxide, and other acid-forming
- Maintain constant hydrogen ion concentration in the cerebral fluids
  - maintain a normal, constant level of neuronal activity.

OXYGEN CONCENTRATION



PO2 below about 30 mm Hg causes vasodilation (normal value is 35 to 40 mm Hg)

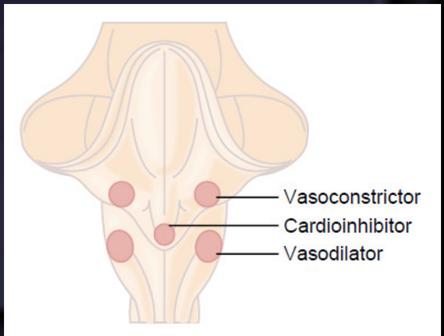
- Oxygen deficiency (hypoxia) mechanism → vasodilation
  - Hypoxia-induced drop in ATP open K_{ATP} channels on smooth muscle
  - causing hyperpolarization and vasodilation
  - returning the brain blood flow
  - transport of oxygen to the cerebral tissues to near normal.
- mechanism is almost exactly the same in the brain as in
  - coronary blood vessels, in skeletal muscle and in most other circulatory areas of the body

Central Nervous System Ischemic Response

- Controls Arterial Pressure by the Brain's Vasomotor Center in Response to Diminished Brain Blood Flow
- When blood flow to the vasomotor center becomes decreased to cause cerebral ischemia—the vasoconstrictor and cardioaccelerator neurons in the vasomotor center respond directly to the ischemia and become strongly excited leading to ↑ systemic arterial pressure
- It can elevate the mean arterial pressure for as long as 10 minutes sometimes to as high as 250 mm Hg.
- Operates when arterial pressure falls far below normal, down to 60 mm Hg and below, reaching its greatest degree of stimulation at a pressure of 15 to 20 mm Hg. "last ditch stand"

Cushing's reflex or Reaction

- It is a special type of CNS ischemic response that results from increased pressure of the cerebrospinal fluid around the brain in the cranial vault.
- For instance, when the cerebrospinal fluid pressure rises to equal the arterial pressure, it compresses the whole brain as well as the arteries in the brain and cuts off the blood supply to the brain
- It helps protect the vital centers of the brain from loss of nutrition if ever the cerebrospinal fluid pressure rises high enough to compress the cerebral arteries



Cerebral "Stroke"

- Most strokes are caused by arteriosclerotic plaques that occur in one or more of the feeder arteries to the brain.
- The plaques can activate the clotting mechanism of the blood & block blood flow in the artery, leading to acute loss of brain function in a localized area.
- In about one quarter of people who develop strokes, high blood pressure makes one of the blood vessels burst; hemorrhage then occurs, compressing the local brain tissue and further compromising its functions.
- The neurological effects of a stroke are determined by the brain area affected.

Cerebral "Stroke"

- Most common types of stroke is blockage of the MCA If blocked on the left side of the brain, Wernicke's area functions are lost (speech comprehension area)
- He or she also becomes unable to speak words because of loss of Broca's motor area for word formation.
- create spastic paralysis of most muscles on the opposite side of the body.
- Blockage of a *posterior cerebral artery* causes loss of vision in both eyes in the half of the retina on the same side as the stroke lesion.