Cerebral, Cutaneous, and Splanchnic Circulation

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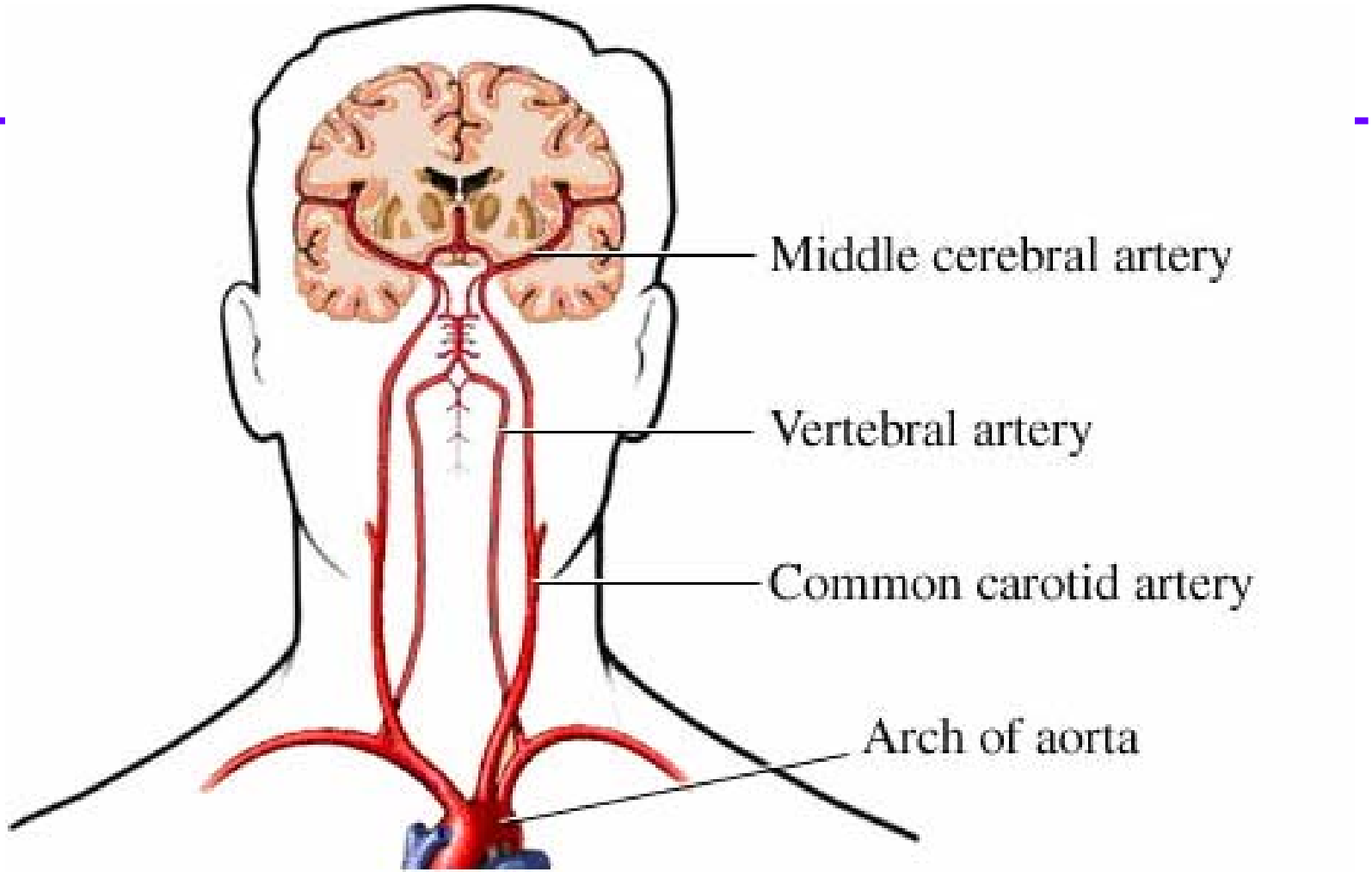

Middle cerebral artery
Vertebral artery
Common carotid artery
Arch of aorta

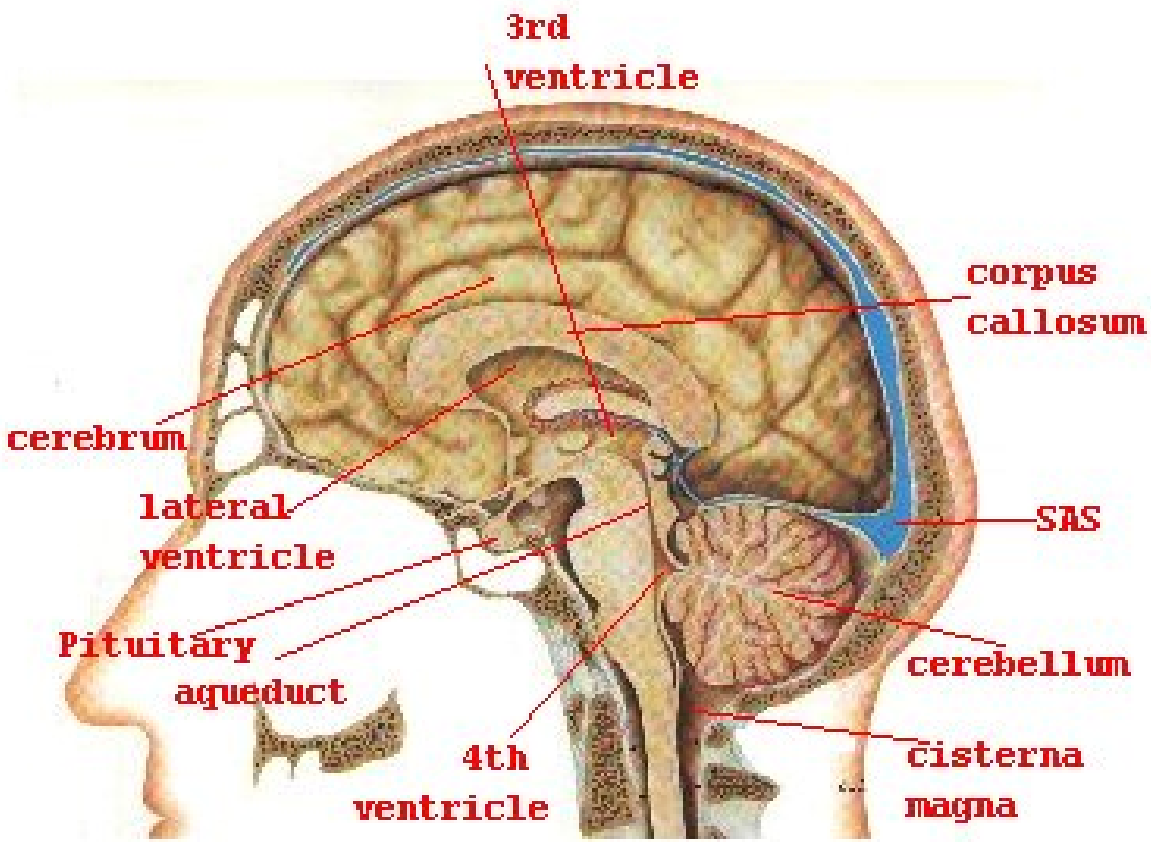
Cerebral Circulation

- Functional Anatomy

BS: Internal carotids (2)
Vertebrals (2) → basilar artery
Circle of Willis (carotids and basilar artery) – origin of 6 large vessels supplying the cerebral cortex
Venous drainage: deep veins
Internal jugular veins
Ophthalmic and pterygoid venous plexuses
Emissary veins to the scalp
Paravertebral veins
Innervation: postganglionic sympathetic neurons
Cholinergic neurons
Postganglionic cholinergic neurons on the blood vessel

Cerebro Spinal Fluid

- Formation and Absorption:
  - CSF fills the ventricles and subarachnoid space
  - Volume = 150 ml
  - Rate of production: 550 ml/day
  - Lateral ventricle (choroid plexus) → 2 interventricular foramina → single midline 3rd ventricle → aqueduct of Sylvius → fourth ventricle → Foramen of Luschka and Magendie → subarachnoid space
  - Absorbed in the arachnoid villi


3rd
ventricle
corpus
callosum
cerebrum
lateral
ventricle
SAS
Pituitary
aqueduct
cerebellum
4th
ventricle
cisterna
magna

CSF

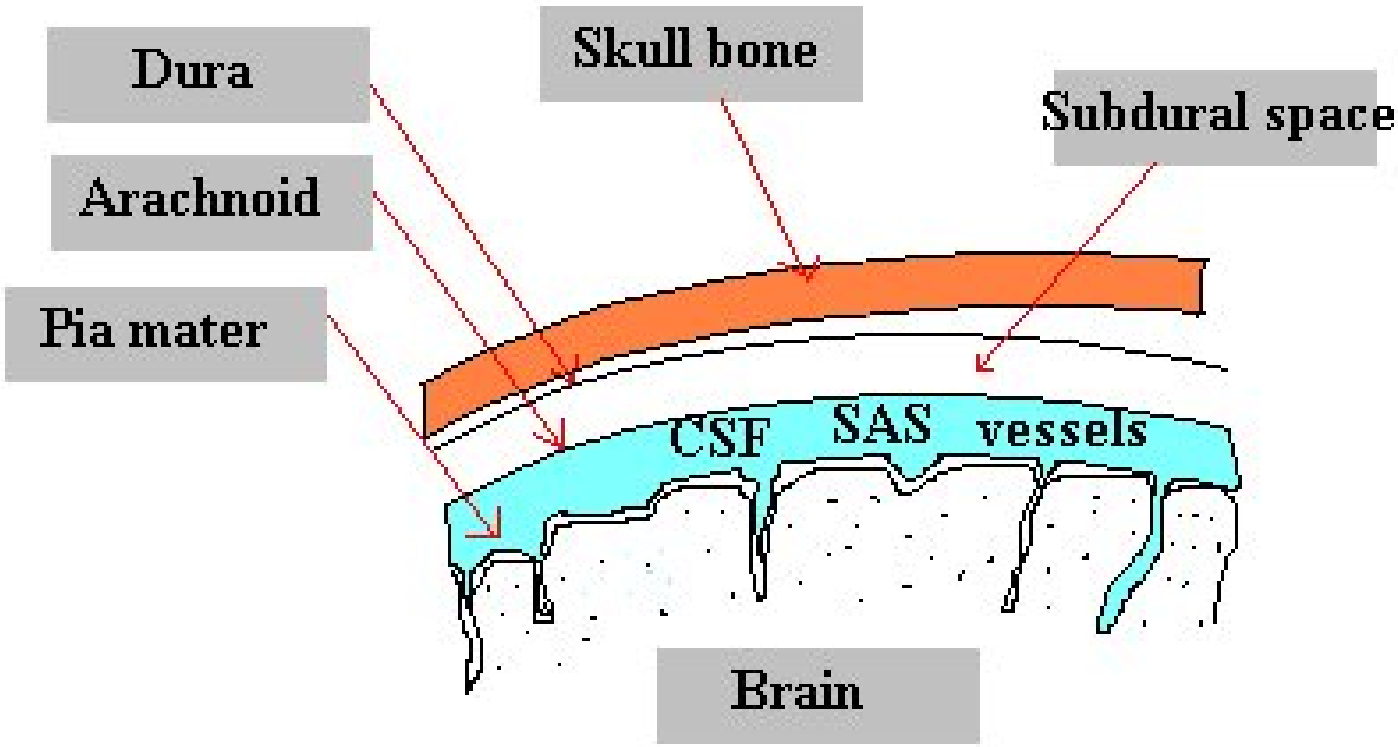
- Composition
  - Essentially the same as that of brain extracellular fluid (15% of the brain volume)
  - Brain interstitial fluid – an ultrafiltrate of plasma with its composition modified by transport processes in the endothelial cells of the cerebral capillaries and the choroid epithelium
  - Lumbar CSF pressure 70 – 180 mm of CSF
  - Up to pressures well above this range, the rate of CSF formation is independent of intraventricular pressure

CSF

- Absorption (bulk flow) is proportionate to the pressure
  - P= 112 mm CSF (average normal CSF pressure) filtration and absorption are equal
  - Below 68 mm CSF absorption stops
  - External / communicating hydrocephalus: decreased reabsorption capacity of arachnoid villi → accumulation of large amounts of fluid
  - Internal / non communicating hydrocephalus: there is obstruction within the ventricular system → fluid accumulate proximal to the block and distends the ventricles

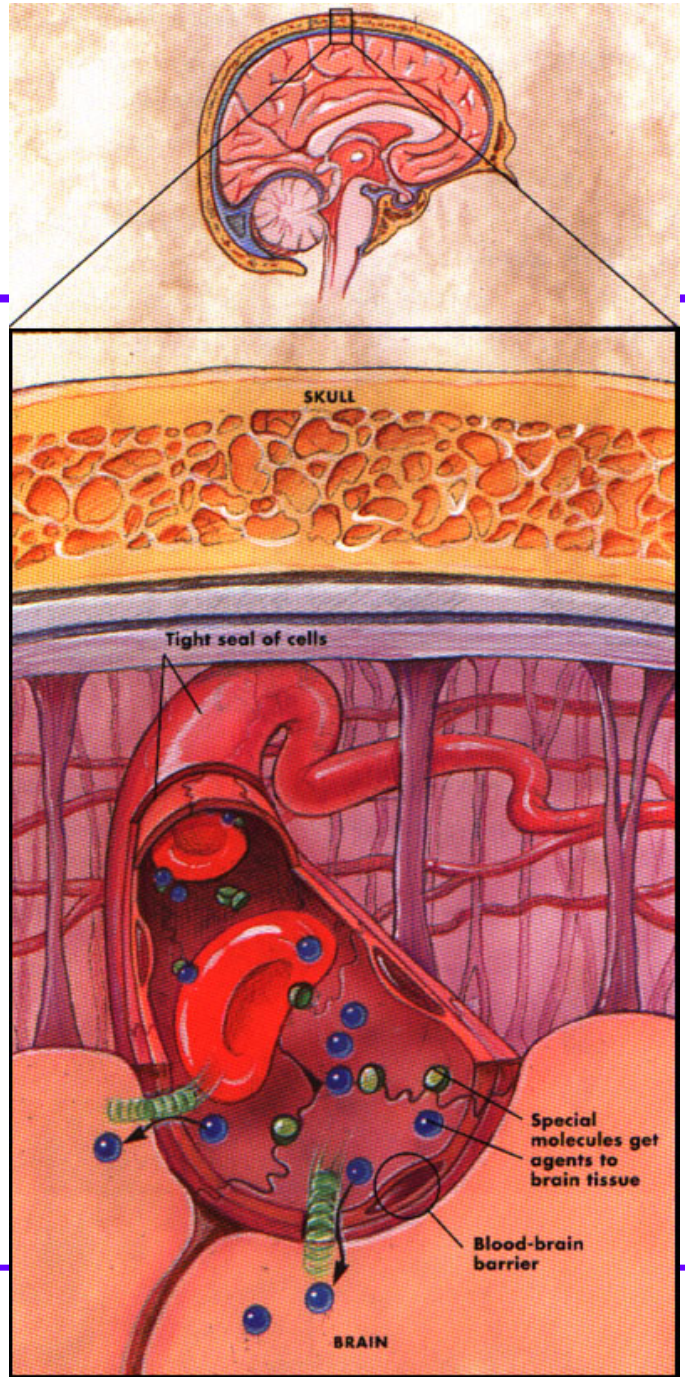
CSF

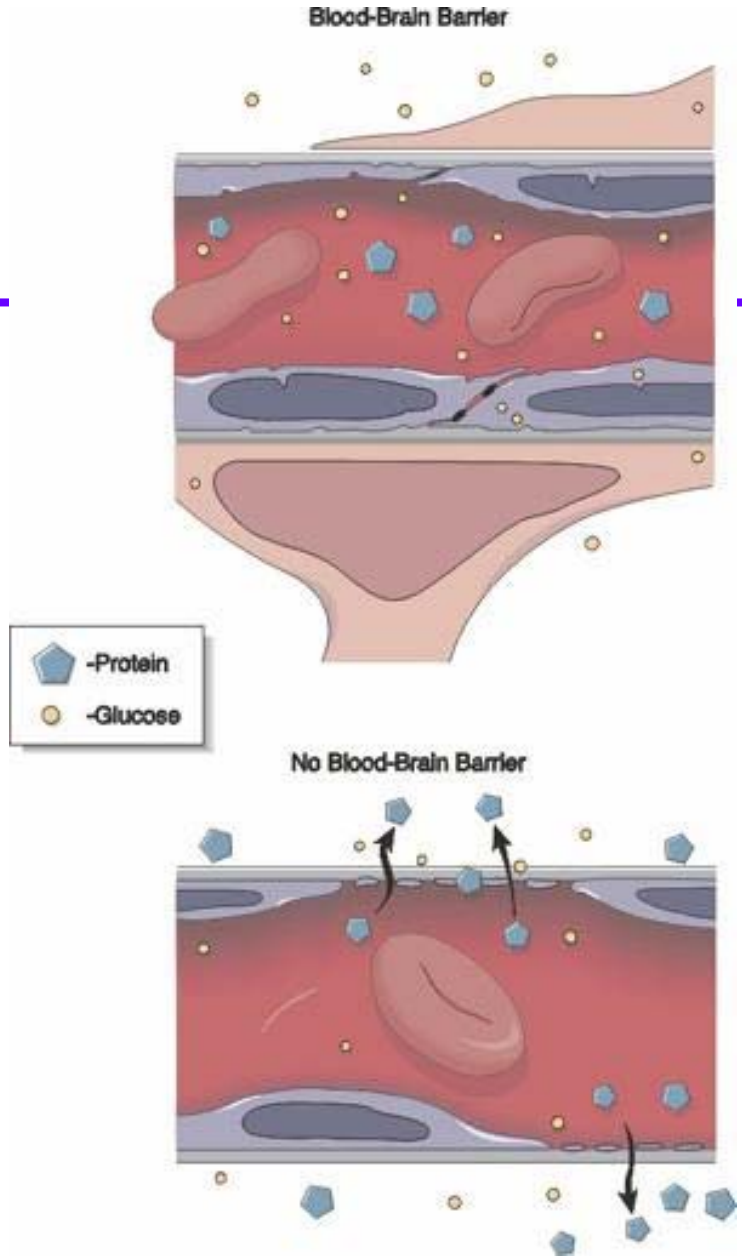
- Protective function (CSF and meninges)
  - There is normally NO “subdural space”
  - Brain support within the arachnoid: blood vessels, nerve roots, and multiple fine fibrous arachnoid trabeculae
  - Brain weighs 1400 gm in air, 50 gm in its water bath of CSF
  - The buoyancy of the brain in the CSF permits its relatively flimsy attachments to suspend it effectively.


Dura
Skull bone
Subdural space
Arachnoid
Pia mater
CSF
SAS
vessels
Brain

The Blood Brain Barrier

- Site: endothelium of cerebral capillaries and the choroid plexus epithelium
- Penetration of substances into brain
  - The rapidity with which substances penetrate brain tissue is inversely related to their molecular size and directly related to their lipid solubility.
  - Water-soluble polar compounds generally cross slowly
  - Water, CO2 and O2 cross readily, glucose cross slowly
  - Bile salts and catecholamines do not enter the adult brain in more than minute amounts
  - Proteins cross to a very limited extent
  - No substance is completely excluded from the brain and the important consideration is the rate of transfer of the substance.


SKULL
Tight seal of cells
Special molecules get agents to brain tissue
Blood-brain barrier
BRAIN


Blood-Brain Barrier
-Protein
-Glucose
No Blood-Brain Barrier

Function of the BBB

- The BBB probably maintains the constancy of the environment of the neurons in the CNS
- Protection of the brain from endogenous and exogenous toxins in the blood and prevention of the escape of neurotransmitters into the general circulation

Clinical implication

- The physician must know the permeability of the BBB to drugs in order to treat diseases of the nervous system intelligently.
- The BBB tends to break down in areas of the brain that are irradiated, infected, or the site of tumors
  - The breakdown helps in identifying the location of tumors

Cerebral Blood Flow

- Average brain weight = 1400 gm
- Normal rate of CBF = 50-65 ml/100 gm/min (750-900 ml/min for the entire brain)
- A striking feature of cerebral function is the marked fluctuation in regional BF with fluctuation in activity.
  - awake but at rest - ↑BF premotor and frontal regions (decoding and analyzing afferent input and with intellectual activity)
  - clenching of right hand – hand area of left motor cortex
  - Talking- bilateral ↑in BF face, tongue, and mouth sensory and motor areas

Cerebral Blood Flow

- 3 metabolic factors with potent effects in controlling CBF
  - 1. Carbon dioxide concentration
  - 2. hydrogen ion concentration
  - 3. oxygen concentration
- An ↑ in either CO_2 or H^+ concentration ↑ CBF
- A ↓ in O_2 concentration ↑ CBF

Carbon Dioxide concentration

- increases CBF by combining 1st with water in the body fluids to form carbonic acid, with subsequent dissociation to form H+.

  $CO_2 + H_2O \rightarrow HCO_3^- + H^+$

- The H+ then cause VD of cerebral vessels: The dilatation being almost directly proportional to the increase in H+ concentration up to a BF limit about 2x normal.
- Any other substance that ↑ the acidity of the brain tissue, and also ↑ the H+ concentration will ↑ BF as well
  - Lactic acid
  - Pyruvic acid

Hydrogen ion concentration

- ↑H+ concentration → ↓neuronal activity
  - It is fortunate that an ↑[H+] → ↑CBF, which in turn carries both CO2 and other acidic substances away from the brain tissues.
  - Loss of CO2 removes carbonic acid from the tissues, reduces [H+] back toward normal

Oxygen concentration

- Except during periods of intense brain activity, the utilization of oxygen by the brain tissue remains within narrow limits.

Stroke

- Blockage of the arterial blood supply to the brain
- Causes:
  - arteriosclerotic plaques that occur in one or more of the feeder artery to the brain
  - High blood pressure that makes one blood vessel to burst
- The neurological effects are determined by the brain area affected
  - Ex. MCA supplies the midportion of brain hemisphere → person becomes almost totally demented: lost of function in Wernicke's speech comprehension area; unable to speak words because of loss of Broca's motor area for word formation

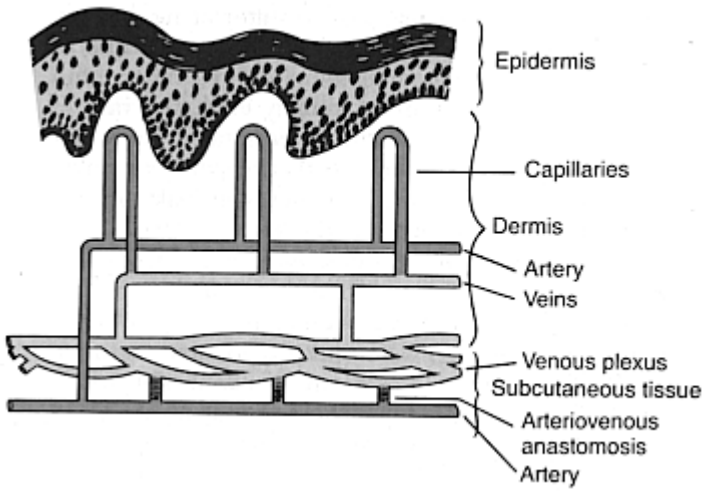
Regulation of Cerebral Circulation

- CBF is autoregulated extremely well between the arterial pressure limits of 60-140 mmHg.
- AP ↓60 or ↑140 without significant change in CBF
- HPN: autoregulatory range shifts to higher pressure levels up to 180-200 mmHg
- AP < 60: CBF compromised
- AP > 140: BF rises rapidly, can cause severe overstretching or rupture of the CBV

Role of Intracranial Pressure

- ↑ICP compresses the cerebral vessels
- Any change in VP causes a similar change in ICP
  - ↑VP ↓CBF (by the effective perfusion pressure and by compressing the BV)
- When ICP is elevated to > 450 mm H2O over a short period, CBF is significantly reduced → ischemia → stimulates the vasomotor area and systemic BP increases proportionately
  - If ICP exceeds AP → cerebral circulation ceases

Cutaneous Circulation



- The skin, subcutaneous tissues, and esp the fat of the subcutaneous are heat insulator for the body.
- The fat conducts heat 1/3 as readily as other tissues

Blood Flow to the skin

- Blood vessels penetrate the fatty subcutaneous insulator tissues and are distributed profusely immediately beneath the skin
- Venous plexus
  - Supplied by inflow of blood from the skin capillaries
  - In exposed areas, blood is supplied here from the small arteries through AV anastomosis
  - Rate of BF varies: above 0 to 30% CO
  - Increase BF causes heat to be conducted from the core of the body to the skin with great efficiency

Reactions of Blood vessels

- White reaction
- Triple reaction
  - Red reaction
  - Wheal
  - Flare
- Reactive hyperemia
- Generalized responses

White Reaction

- When a pointed object is drawn lightly over the skin, the stroke lines become pale.
- The mechanical stimulus apparently initiates contraction of the precapillary sphincters, and blood drains out of the capillaries and small veins.
- appears in about 15 seconds

Triple reaction

- Part of normal reaction to injury; present after total sympathectomy
- Red reaction: reddening at the site that appears in about 10 seconds when the skin is stroked more firmly with a pointed instrument
  - This is followed in a few minutes by a local swelling and diffuse, mottled reddening around the injury
  - Due to capillary dilation and a direct response of the capillaries to pressure

Triple reaction

- Wheal: local edema due to increase permeability of the capillaries and post capillary venules with consequent extravasation of fluid
  - Produced in part by histamine or a histamine-like substance released from local mast cells and mediated via H1 receptors
- Flare: the redness spreading out from the injury
  - due to arteriolar dilation

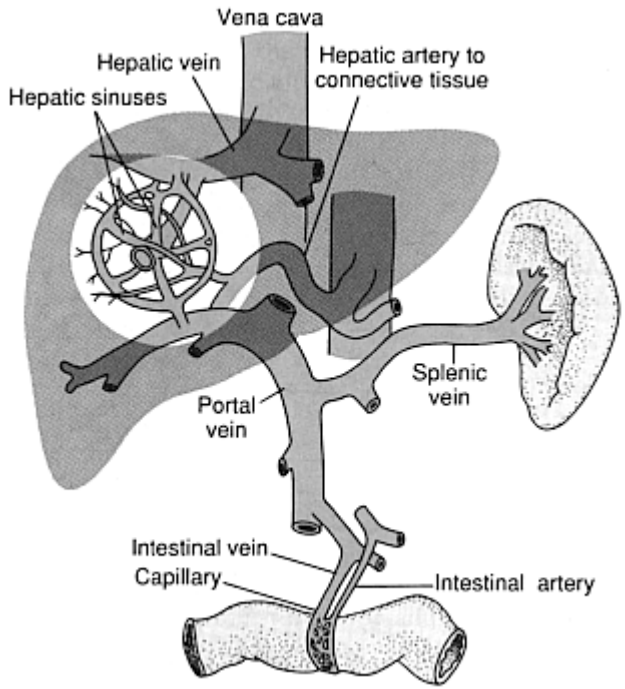
Reactive hyperemia

- A response of the blood vessels that occurs in many organs but is visible in the skin
- An increase in the amount of blood in a region when its circulation is reestablished after a period of occlusion.
- prevented if the circulation of the limb is occluded in an atmosphere of 100% oxygen

Generalized responses

- Nor adrenergic nerve stimulation and circulating epinephrine and norepinephrine constrict cutaneous blood vessels
- Vasodilation is brought about by a decrease in constrictor tone as well as local production of bradykinin in sweat glands and vasodilator metabolites
- Cold blue or gray skin: the arterioles are constricted and the capillaries are dilated
- Warm red skin: arterioles and capillaries are dilated
- Shock: more profound in patients with elevated temperature because of the cutaneous vasodilation.

Splanchnic Circulation



- Includes BF through the gut, spleen, pancreas, and liver
- All the blood that courses through the gut, spleen, and pancreas flows immediately into the liver by way of the portal vein
- In the liver, the blood passes through millions of fine liver sinusoids and finally leaves the liver by way of the hepatic veins that empty into the vena cava

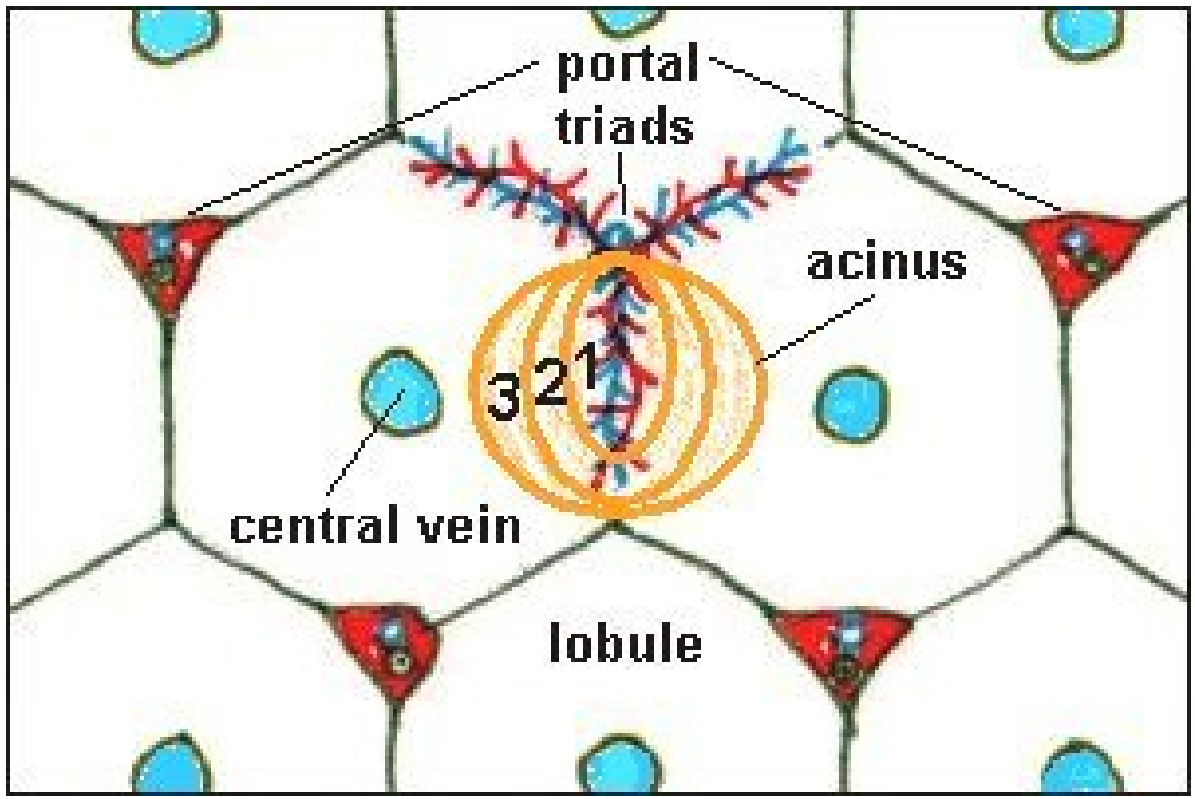
Blood flow to the liver

- About 1100ml of blood flows from the portal vein into the liver sinusoids each minute
- Additional 350 ml flows into the sinusoids from the hepatic artery
- Average total = 1450 ml/min; 29% of the total resting CO, almost 1/3 of the total body blood flow
- Blood from the intestines, pancreas, and spleen drains via the portal vein to the liver, and from the liver via the hepatic veins to the IVC
- Viscera receives 30% of CO via celiac, SMA, IMA
- Liver receives 1000 ml/min from portal vein and 500 ml/min from hepatic artery

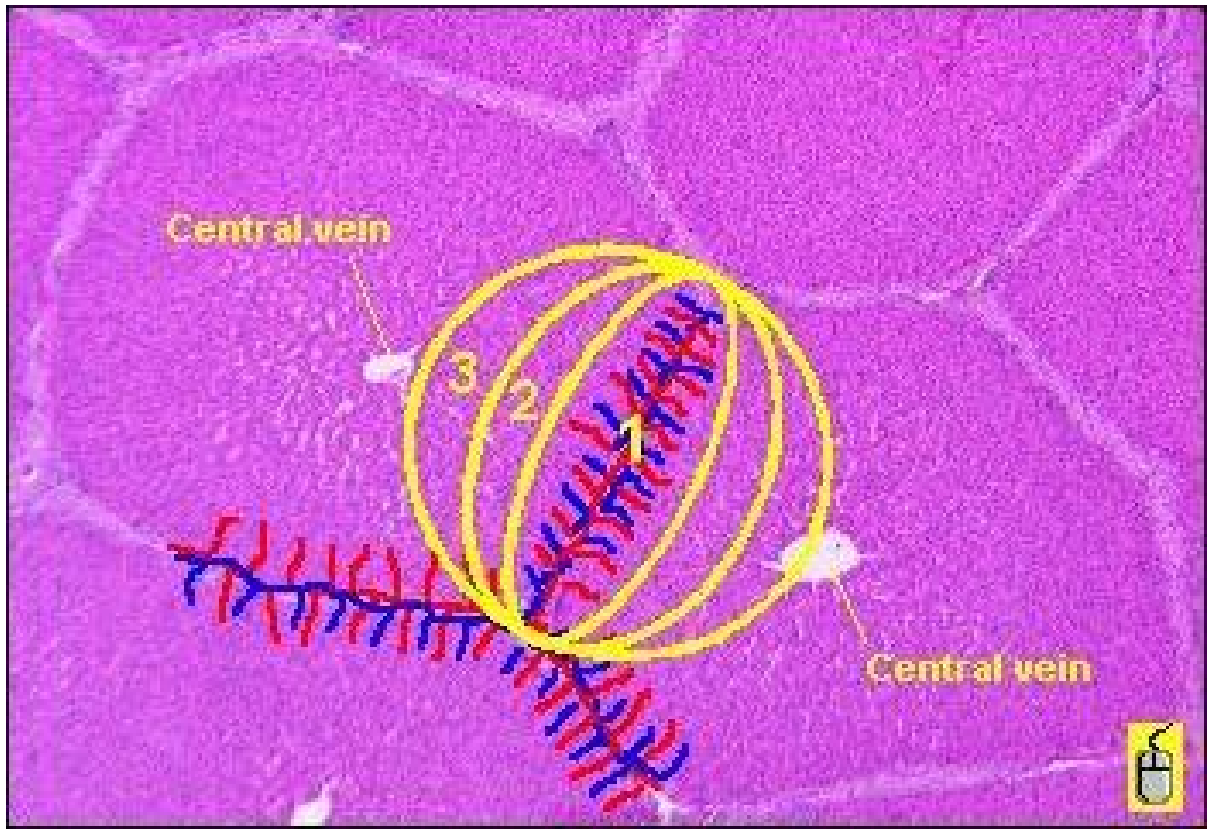
Intestinal Circulation

- BS: SMA, IMA
- blockage of a large intestinal artery → infarction in the bowel
- BF is greater in the mucosa
- BF responds to changes in metabolic activity
  - BF to the SI doubles after a meal (lasts up to 3 hours)
- capable of extensive autoregulation

Hepatic Circulation



Anatomy



Hepatic blood flow

- 25% of Cardiac output
- 75% portal vein
- 25% hepatic artery
- The capillary network of the liver are the sinuses that radiate towards the periphery of the acinus where they connect with the terminal hepatic venules
- Capacitance function: contains 15% of total blood volume of the body

Hepatic Circulation

- Portal venous pressure 10 mmHg
- Hepatic venous pressure 5 mmHg
- Mean pressure in the hepatic arterial branches that converge on the sinusoids 90 mmHg
- Pressure in the sinusoids is lower than portal venous pressure (2-3 mmHg above hepatic veins)
- Pressure drop is adjusted so that there is an inverse relationship between hepatic arterial and portal venous blood flow