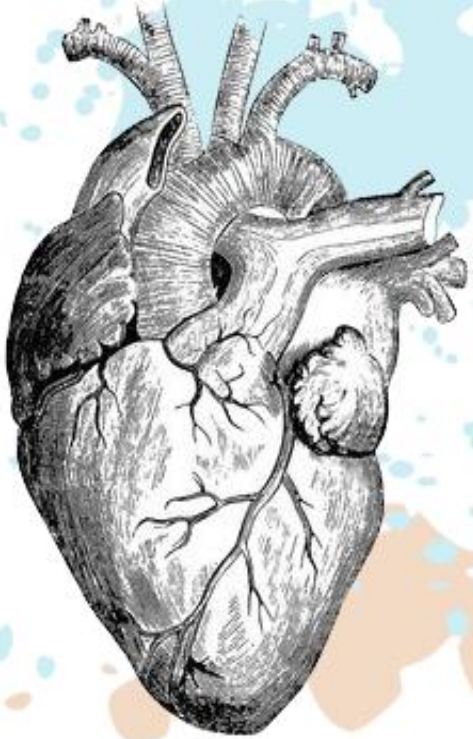

Very important

Extra information

Physiology

OF THE CARDIOVASCULAR SYSTEM

* Guyton corners, anything that is colored with grey is EXTRA explanation

SHOCK

Objectives :

- Define circulatory shock.
- Describe the types and causes of shock.
- Body compensatory mechanisms during reversible phases of hemorrhagic shock.
- Mechanisms responsible for the irreversible phase of hemorrhagic shock.

Contact us : Physiology435@gmail.com

SHOCK

Before you start, just refresh your mind:

The basic unit of life is the **Cell** → Gets its needed energy to stay alive.

No oxygen = no energy = no life

The cell obtains energy from:
1. Oxygen.
2. Breaking down of glucose (cellular respiration)

Shock (Circulatory Shock)

- What is it?

Any condition in which the **circulatory** system is **unable** to provide adequate circulation & tissue perfusion, resulting in:

* **failure to deliver oxygen to the tissues** & vital body organs relative to its metabolic requirement.
* organ dysfunction.
* cellular damage.

If not **quickly** corrected, it may lead to **irreversible shock** leads to death.

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circulatory shock

The main problem is in **less cardiac output**

Low Output Shock

- Cardiogenic
- Hypovolemic
- Obstructive

The main problem is in the **less peripheral resistant.**

High or normal Output Shock

- Distributive Neurogenic/Spinal
- Distributive vasogenic
  - Anaphylactic
  - Psychogenic
  - Septic \ toxic

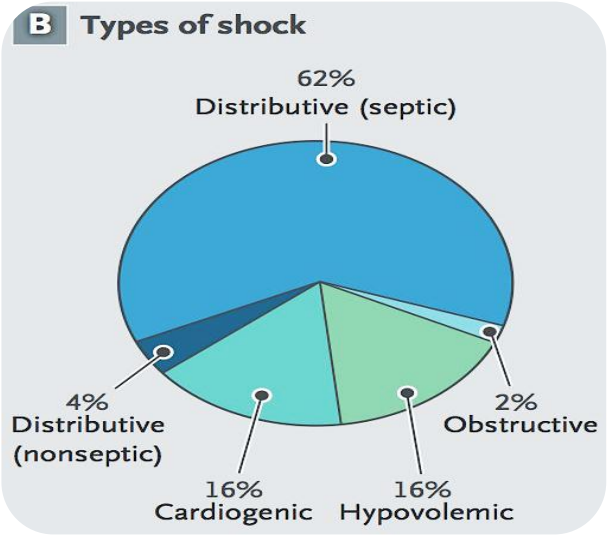
Notes:

- Shock is also called (circulatory shock), because there is **failure** in the circulation (perfusion.)
- The sequence of shock is :

No tissue perfusion → no oxygen → cellular hypoxia → dysfunction of vital organs → death of cell → organs failure.

Distribution of shock

- **Hypovolemic-** most common type**:** Hemorrhagic, occult fluid loss.
- **Cardiogenic:** Ischemia, arrhythmia, valvular, myocardial depression.
- **Distributive:** Anaphylaxis, sepsis, neurogenic
- **Obstructive:** Tension pneumo, pericardial temponade, Pulmpnary embolism (PE)



Notes:
- The net result of circulatory shock is **low arterial pressure**.
- In the distributive shock (problem in the peripheral resistant): firstly the cardiac output will be **high** or normal → then there will be massive vasodilatation → accumulation of blood in veins → decrease venous return → eventually cause **decrease in cardiac output**.

Hypovolemic shock

Low CO due to

•Inadequate plasma\blood volume (loss of 15-25% \ 1-2L).

عند فقدان المريض لهذه الكمية من السوائل
هنا نعتبر أنه في حالةshock

•Reduced venous return (preload).

عند انخفاض كمية الدم الداخلة إلى القلب، من الطبيعي بالتالي انخفاض كمية الدم الخارجة منه

*NOTE :
The problem is in **Cardiac output**
[MAP = CO X PR]

Causes

- **Loss of blood (hemorrhagic shock 'common') :**
  - **External:** trauma , GIT bleeding
  - **Internal:** hematoma, hemothorax or hemoperitoneum.
- **Loss of plasma : burns** , exfoliative dermatitis .
- **Loss of fluid**

- External: vomiting , diarrhea , excessive sweating , hyperosmolar states (diabetic ketoacidosis , hyperosmolar nonketotic coma).

- Internal:(third-spacing) ; pancreatitis , ascites , bowel obstruction.

Symptoms

- **Hypotension** (≤ 85/40 mmHg)
- **Tachycardia** (Compensation for ↓ MAP sensed by Baroreceptors)
- **Rapid, weak, & thready pulse** (140/min).
- **Intense thirst.**
- **Tachypnea** "rapid respiration" (Compensation for hypoxia sensed by Chemoreceptors).
- **Restlessness** due to hypo-perfusion.
- **Cold, pale skin** (due to hypo-perfusion).
- **Oliguria** (low urine output)/ **Anuria** (no urine output).
- **Blood test:** Lactic acidosis.

- **Guyton corner :** hypovolemic means diminished blood volume. Hemorrhage is the most common cause of hypovolemic shock. Hemorrhage decrease the filling pressure of the circulation and , as a consequence decrease venous return. As a result, the CO falls below normal and shock may ensue.

Cardiogenic shock

Low CO due to	Causes	Symptoms	Other
• **Failure** of myocardial pump, despite adequate ventricular filling pressure. *NOTE : The problem is in **Cardiac output** [MAP = CO X PR]	• **Myocardial infarction** (most common) • **Cardiomyopathy** • **Myocarditis** • **Cardiac tamponade** • **Acute valvular dysfunction e.g. (**rupture of papillary muscle post MI). • **Congestive heart failure** • **Sustained arrhythmias e.g. (**heart block , ventricular tachycardia). • **Pulmonary embolism.** • **Sepsis**	• Similar signs & symptoms to that of hypovolemic shock. **Congestion of lungs & viscera (Chest X-ray):** • Interstitial pulmonary edema. • Alveolar edema. • Cardiomegaly..	• Is associated with loss of more than 40% of left ventricular myocardial function. • Mortality rate is high (60-90%)

- The cardiac tamponade is : fluid accumulates in the pericardium resulting in impeding the stretch of pericardial sac.
- You can indicate if there is cardiogenic shock by : ejection fraction (normally it's 0.54 , if it decrease more than 40% it indicate as cardiogenic shock)

Obstructive shock

- **Cardiac output is <u>reduced</u> by vascular obstruction :**

obstruction of venous return	Compression of the heart	Obstruction of the outflow of the heart
• Example : Vena Cava syndrome (usually neoplasms)	• Example : hemorrhagic pericarditis → cardiac tamponade.	• Aortic dissection. • Massive pulmonary embolism. • pneumothorax

*NOTE :
The problem is in **Cardiac output** [MAP = CO X PR]

Distributive Shock: High / Normal Output

General information

- CO is normal or elevated
- Distribution is inappropriate
- Shock is due to loss of vascular resistance

Mean Arterial Pressure (MAP)

The problem is in Peripheral Resistance

MAP = CO X PR

Classification

- Distributive Vasogenic
  - Anaphylactic
  - Septic / Toxic
  - Psychogenic
- Distributive Neurogenic/Spinal (Venous pooling)

- Venous pooling mean : accumulation of blood in veins which will affect the venous return.

Distributive Vasogenic

Anaphylactic

- Massive & generalized allergic reaction
- Histamine triggers peripheral vasodilation and increase capillary permeability
- Can lead to low output distributive shock
- IgE- mediated hypersensitivity

Septic / Toxic (endotoxic shock)

- Bacterial endotoxin triggers peripheral vasodilatation and endothelial injury
- Hyperdynamic state
- **Signs & symptoms:** Patient flushed & warm → due to his Hyperdynamic state.

Psychogenic

- Simple fainting (syncope)
- Caused by stress, pain, or fright
- Decrease HR & vessels dilate
- Brain becomes hypoperfused
- Loss of consciousness

- Septic distributive shock caused by : the endotoxin of bacteria (either gram +ve or gram -ve)

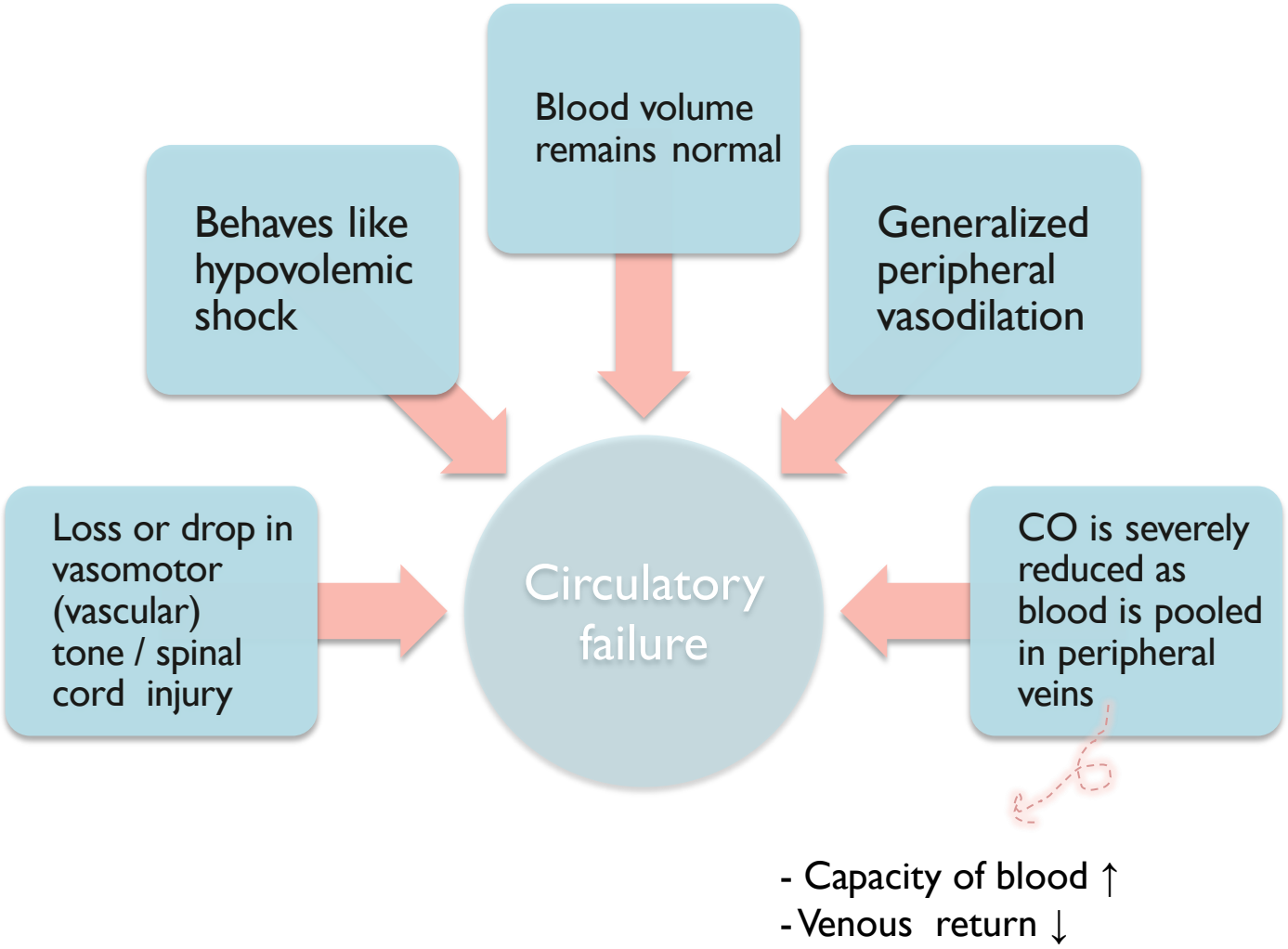
Guyton corner

Guyton corner :

- Occasionally, cardiac output is **normal or even greater than normal**, yet the person is in circulatory shock. This can result from (1**) excessive metabolic rate**, so even a normal cardiac output is inadequate, or (2**) abnormal tissue perfusion patterns**, so most of the cardiac output is passing through blood vessels besides those that supply the local tissues with nutrition.
- **Anaphylaxis** is an allergic condition in which the **cardiac output** and **arterial pressure** often **decrease** drastically. It results primarily from an **antigen-antibody reaction** that rapidly occurs after an antigen to which the person is sensitive enters the circulation. One of the principal effects is to cause the basophils in the blood and mast cells in the per-capillary tissues to release histamine or a histamine-like substance. The histamine causes (1) an **increase in vascular capacity** because of venous dilation, thus causing a marked **decrease in venous return**; (2) **dilation of the arterioles**, resulting in greatly **reduced arterial pressure**; and (3) greatly **increased capillary permeability**, with rapid **loss of fluid and protein** into the tissue spaces. The net effect is a great reduction in venous return and sometimes such serious shock that the person dies within minutes. Intravenous injection of large amounts of histamine causes "histamine shock," which has characteristics almost identical to those of anaphylactic shock.
- Septic shock refers to a **bacterial infection** widely disseminated to many areas of the body, with the infection being **borne** through the blood from one tissue to another and causing extensive damage.
- There are many varieties of septic shock because of the many types of bacterial infections that can cause it and because infection in different parts of the body produces different effects.
- other than cardiogenic shock, septic shock is the most frequent cause of shock-related death in the modern hospital.
- In early stages of septic shock, the patient usually **does not have signs of circulatory collapse** but only signs of the bacterial infection.

As the infection becomes more severe, the circulatory system usually becomes involved either because of direct extension of the infection or secondarily as a result of toxins from the bacteria, with resultant loss of plasma into the infected tissues through deteriorating blood capillary walls. There finally comes a point at which deterioration of the circulation becomes progressive in the same way that progression occurs in all other types of shock. The end stages of septic shock are not greatly different from the end stages of hemorrhagic shock, even though the initiating factors are markedly different in the two conditions.

Distributive Neurogenic/Spinal (Venous pooling)



- **Guyton corner :**

- **In *neurogenic shock,*** Shock occasionally results without any loss of blood volume. Instead, the *vascular capacity* increases so much that even the normal amount of blood becomes incapable of filling the circulatory system adequately. One of the major causes of this is *sudden loss of vasomotor tone* throughout the body, resulting especially in massive dilation of the veins.

- **Causes of Neurogenic Shock:**

1. *Deep general anesthesia* often depresses the vasomotor center enough to cause vasomotor paralysis, with resulting neurogenic shock.

2. *Spinal anesthesia,* especially when this extends all the way up the spinal cord, blocks the sympathetic nervous outflow.

3. *Brain damage* is often a cause of vasomotor paralysis. Also, even though brain ischemia for a few minutes almost always causes extreme vasomotor stimulation, prolonged ischemia (lasting longer than 5 to 10 minutes) can cause the opposite

Distributive Neurogenic/Spinal

Causes of neurogenic shock :

- Acute spinal cord injury
- Deep general anesthesia depresses the vasomotor center
- Spinal anesthesia blocks the sympathetic nervous system
- Brain damage can be a cause of vasomotor paralysis

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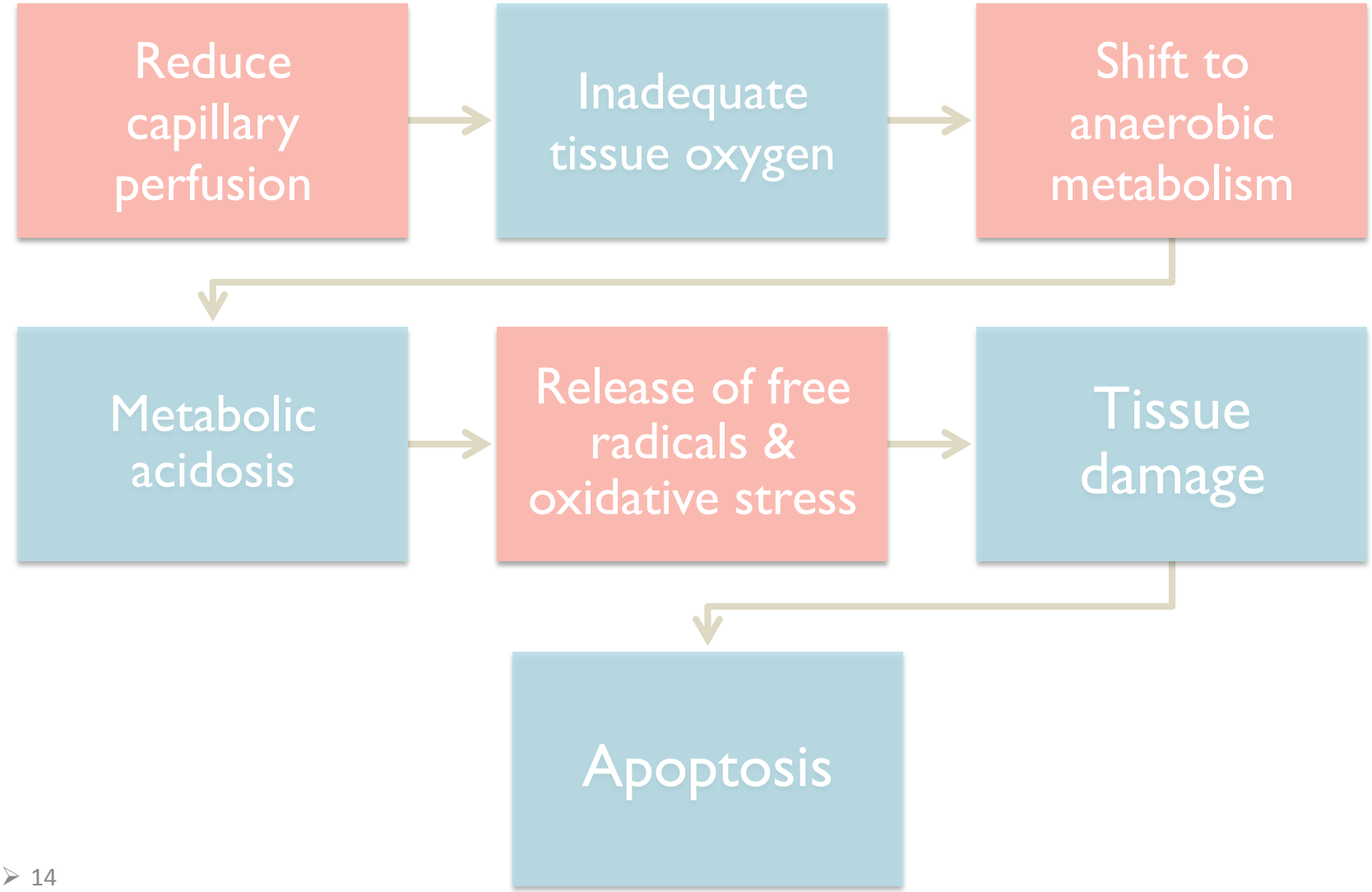
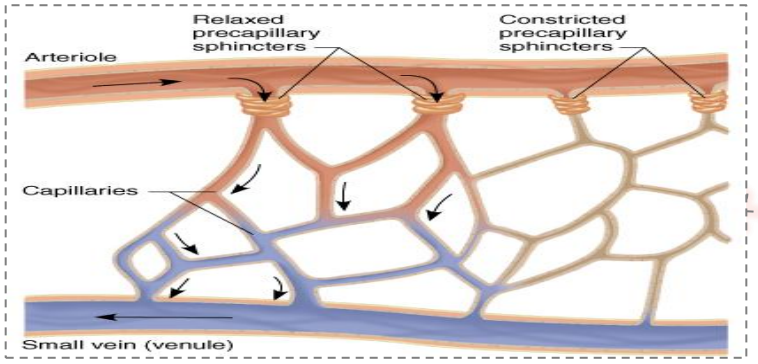
Pathophysiology of Shock



METABOLIC CHANGES & CELLULAR RESPONSE TO SHOCK

Spasm of pre/post capillary sphincters:

reduced capillary perfusion → hypoxic tissue damage, (oxidative stress) → anaerobic metabolism (anaerobic glycolysis) → Lactic acid production → metabolic acidosis (intracellular acidosis). → Failure of Na+/K+ pump (inc [Na+] & [C++]) → Lysosomes, nuclear membranes & mitochondrial breakdown



- The blood comes out from the heart to all the body throw aorta → to artery to → arteriole → to capillary → to venule to → vein then come back to the heart.
- between arteriole/venule and capillary there is capillary sphincters which are somehow control the blood flow , so when there is spasm of these pre/post capillary sphincters that will affect capillary perfusion.

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METABOLIC CHANGES & CELLULAR RESPONSE TO SHOCK

2 › After 3 - 5 hours of shock :

precapillary sphincters dilate (venules are still constricted). → blood stagnation in capillaries. → hypoxia continue + fluid leaves to extra vascular compartment. → further reduction in circulating blood volume.

3 › Granulocytes accumulation at injured vessels → free radicals release → further tissue damage.

METABOLIC CHANGES & CELLULAR RESPONSE TO SHOCK

4 › **Damage in GIT mucosa → allows bacteria into circulation.**

5 › **Cerebral ischemia → depression of VMC** "vasomotor center (sympathetic)" → **vasodilation + ↓ HR [** further decrease in blood pressure **].**

6 › **Myocardial ischemia → depressed contractility + myocardial damage [** more shock & acidosis **].**

7 › **Respiratory distress syndrome occurs due to damage of capillary endothelial cells & alveolar epithelial cells, with release of cytokines.**

8 › **Multiple organ failure & death.**

Guyton corner : At times, a person may be in severe shock and still have an almost normal arterial pressure because of powerful nervous reflexes that keep the pressure from falling. At other times, the arterial pressure can fall to half of normal, but the person still has normal tissue perfusion and is not in shock.

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Compensatory mechanisms

1 › Sympathetic stimulation:

- Baroreceptor reflex: stimulated by the decrease in blood pressure
- Chemoreceptor reflex: stimulated by acidosis

2 › Renin-Angiotensin system activation:

- Angiotensin II & III: powerful vasoconstrictors
- Aldosterone: Na+ & water retention

3 › The release of antidiuretic hormone (vasopressin):

- Water retention, vasoconstriction and thirst stimulation

4 › Plasma protein synthesis.

5 › Fluid shift mechanism "explained in the next slides"

- **Guyton corner** : 13th edition p. 294-295

Sympathetic stimulation in compensation of shock causes 3 major events:

1. Arterioles constrict: increasing peripheral resistance (no effect on CO)
2. Veins and venous reservoirs constrict: increasing venous return and cardiac output
3. Heart activity increases: increasing heart rate

One more compensatory mechanism that's mentioned in the book:

Increased secretion of the adrenal medullae of epinephrine and norepinephrine, which constricts the peripheral arterioles and veins and increases the heart rate.

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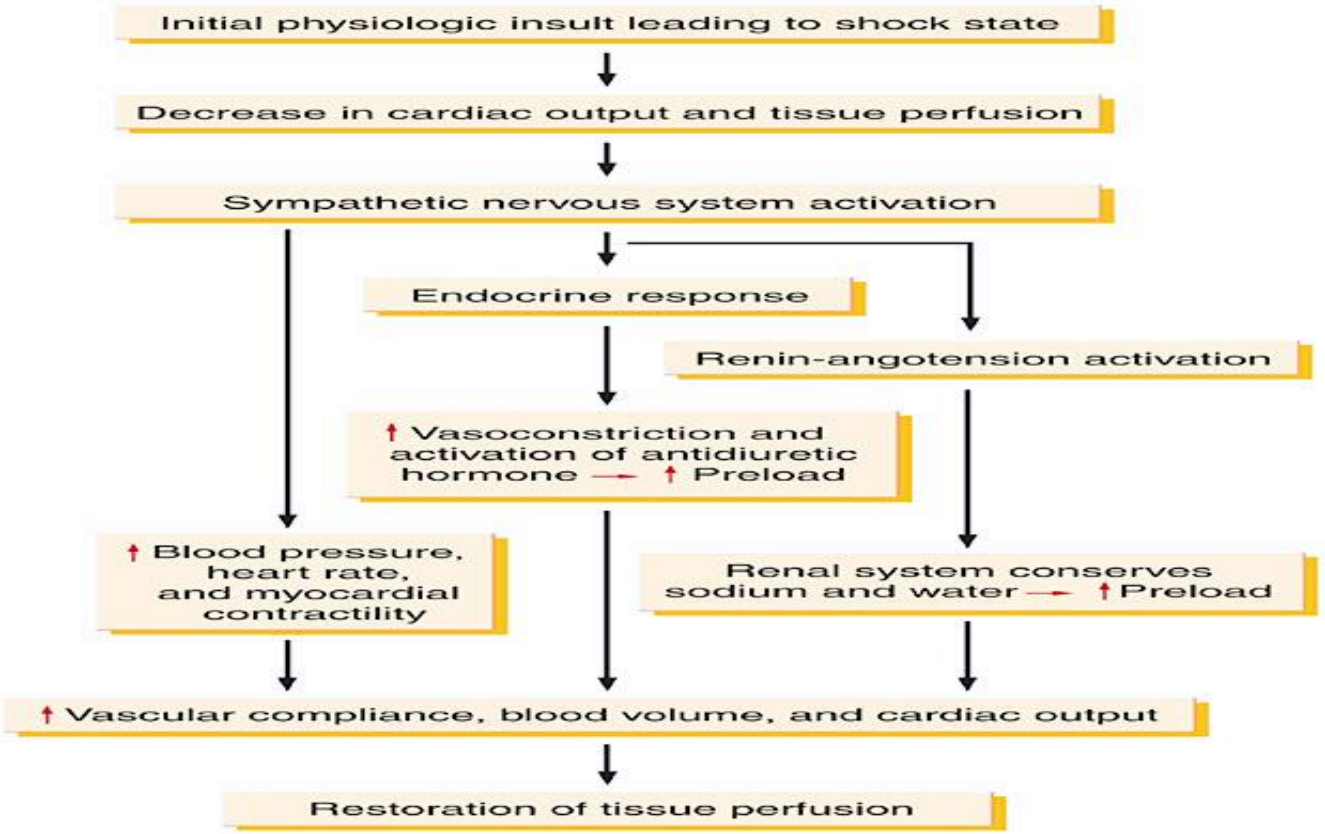
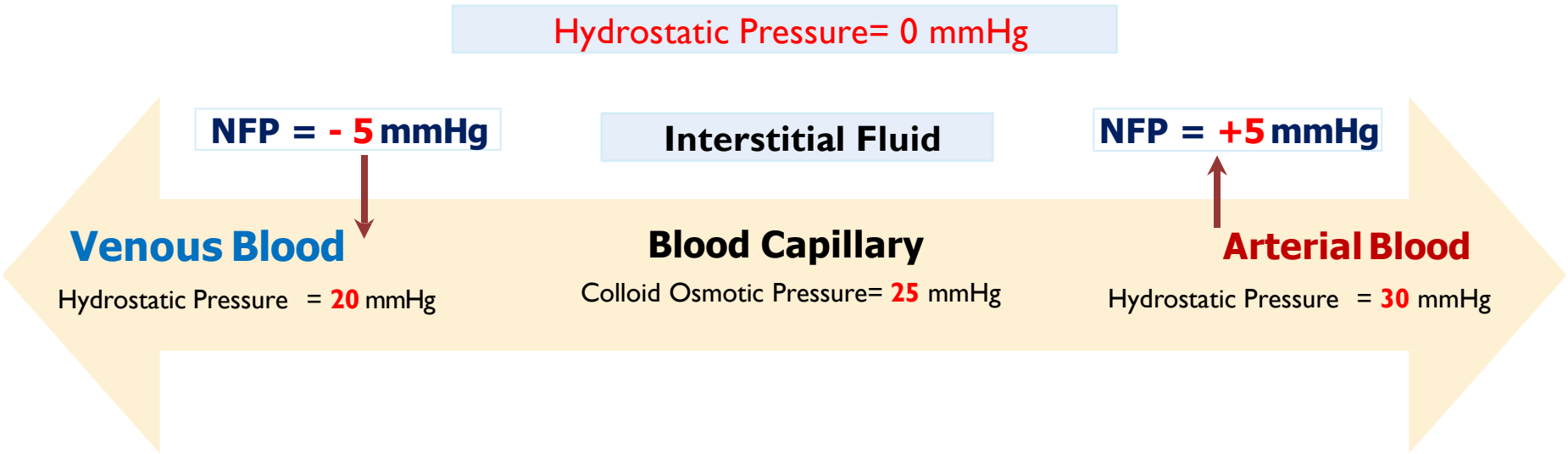
Compensatory Mechanisms



IN NORMAL MICROCIRCULATION



At arterial end:

- Water moves **out** of the capillary with a NFP of +5 mmHg.
- Hydrostatic pressure dominates at the **arterial** end & net fluid flows out of the circulation.

At venous end:

- Water moves **into** the capillary with a NFP of -5 mmHg.
- Oncotic pressure dominates at the **venous** end & net fluid will flow into the bloodstream.

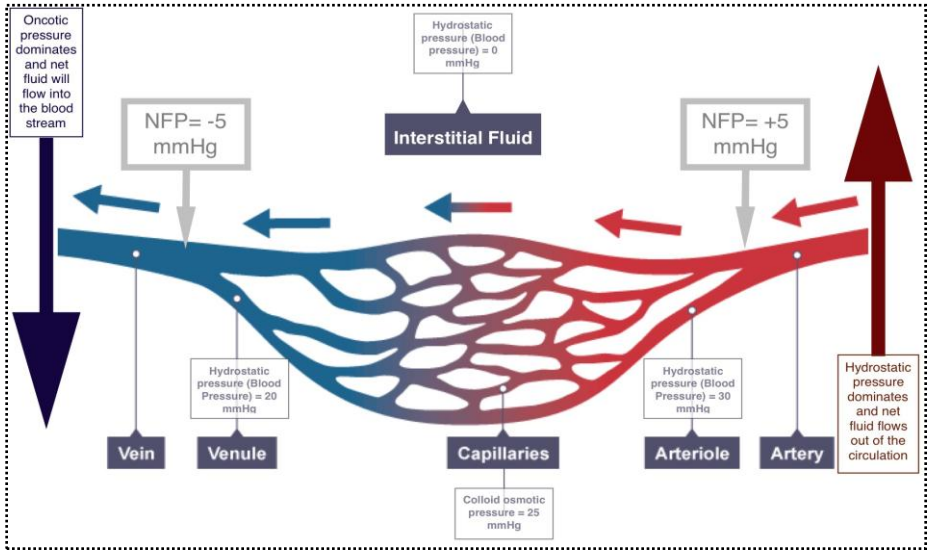
* NFP = Net Filtration Pressure

Fluid-Shift mechanism

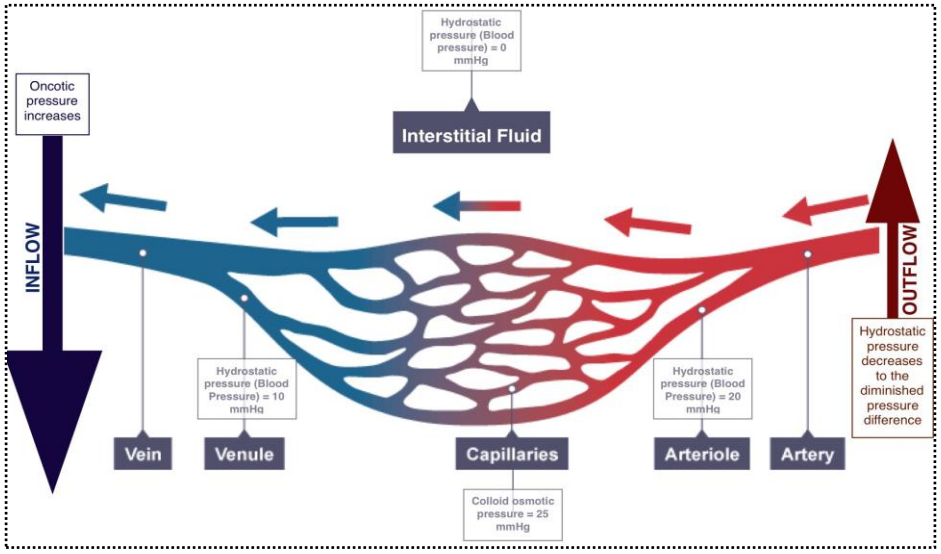
- In shock, the hydrostatic pressure decreases & oncotic pressure is constant, as a result:
  - The fluid exchange from the capillary to the extracellular space decreases.
  - The fluid return from the extracellular space to the capillary increases.

- That will increase the blood volume & will increase BP helping to compensate shock.

Normally



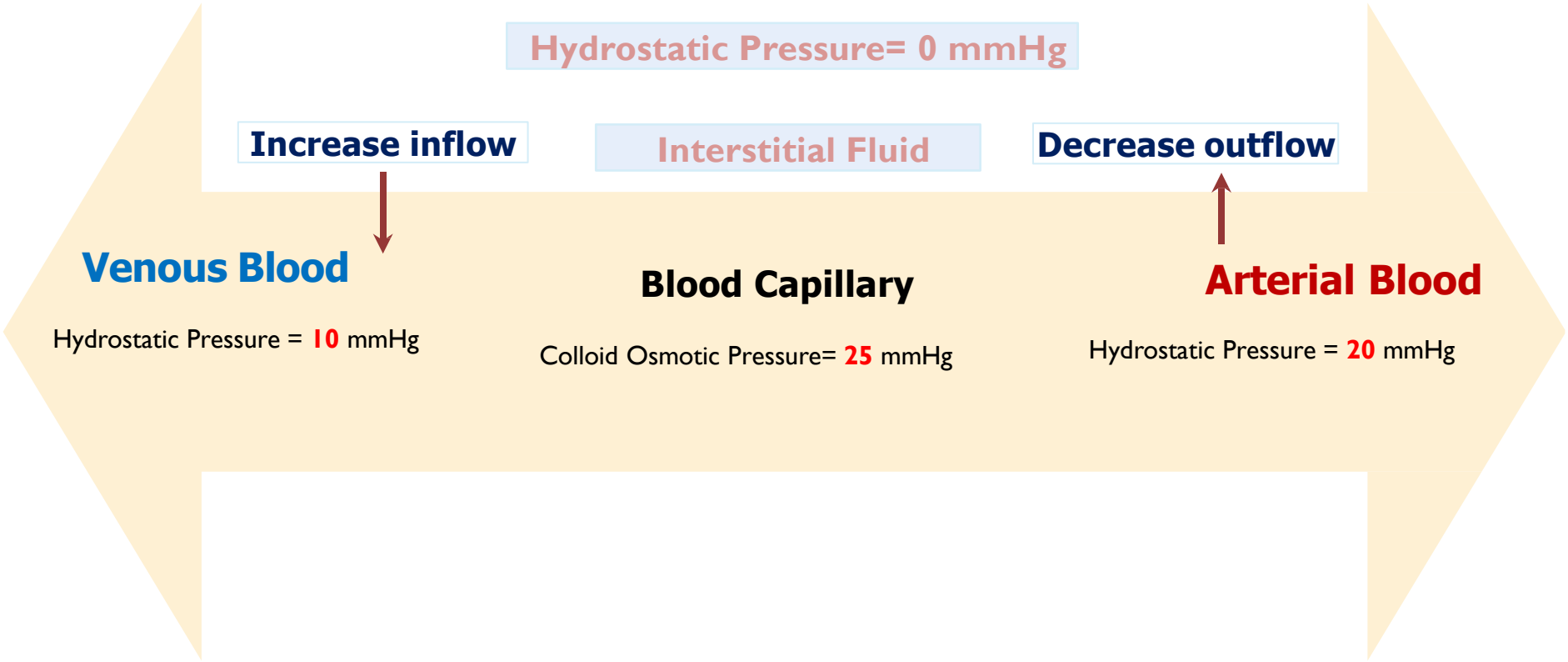
During Fluid-Shift



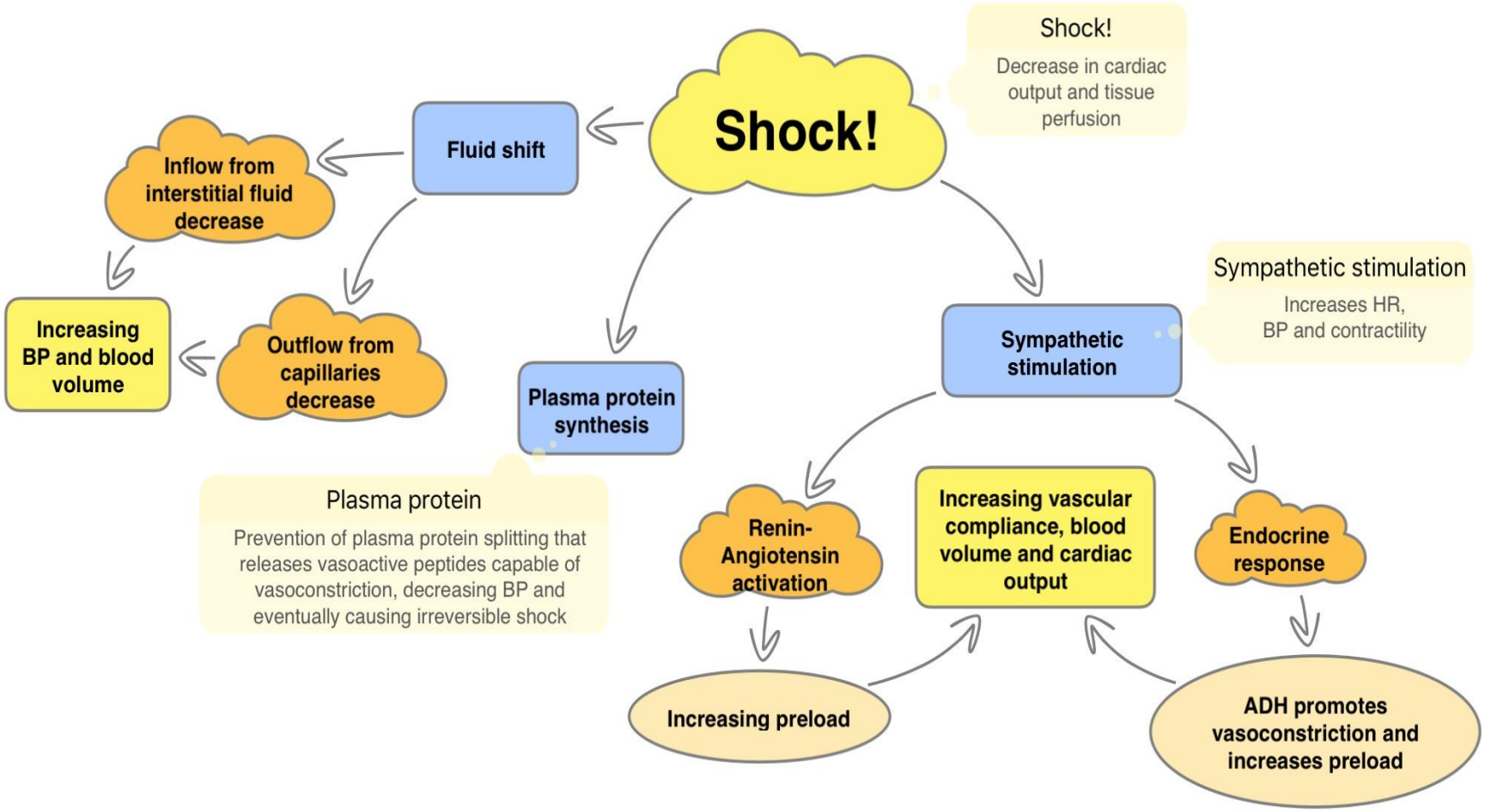
- **Guyton corner :**

The capillary fluid shift mechanism means simply that anytime capillary pressure falls too low, fluid is absorbed from the tissues through the capillary membranes and into the circulation, thus building up blood volume and increasing the pressure in the circulation.

Fluid-Shift mechanism In Shock



Summary


Shock!
Shock!
Decrease in cardiac output and tissue perfusion
Fluid shift
Inflow from interstitial fluid decrease
Increasing BP and blood volume
Outflow from capillaries decrease
Plasma protein synthesis
Plasma protein
Prevention of plasma protein splitting that releases vasoactive peptides capable of vasoconstriction, decreasing BP and eventually causing irreversible shock
Sympathetic stimulation
Sympathetic stimulation
Increases HR, BP and contractility
Renin-Angiotensin activation
Increasing vascular compliance, blood volume and cardiac output
Endocrine response
Increasing preload
ADH promotes vasoconstriction and increases preload

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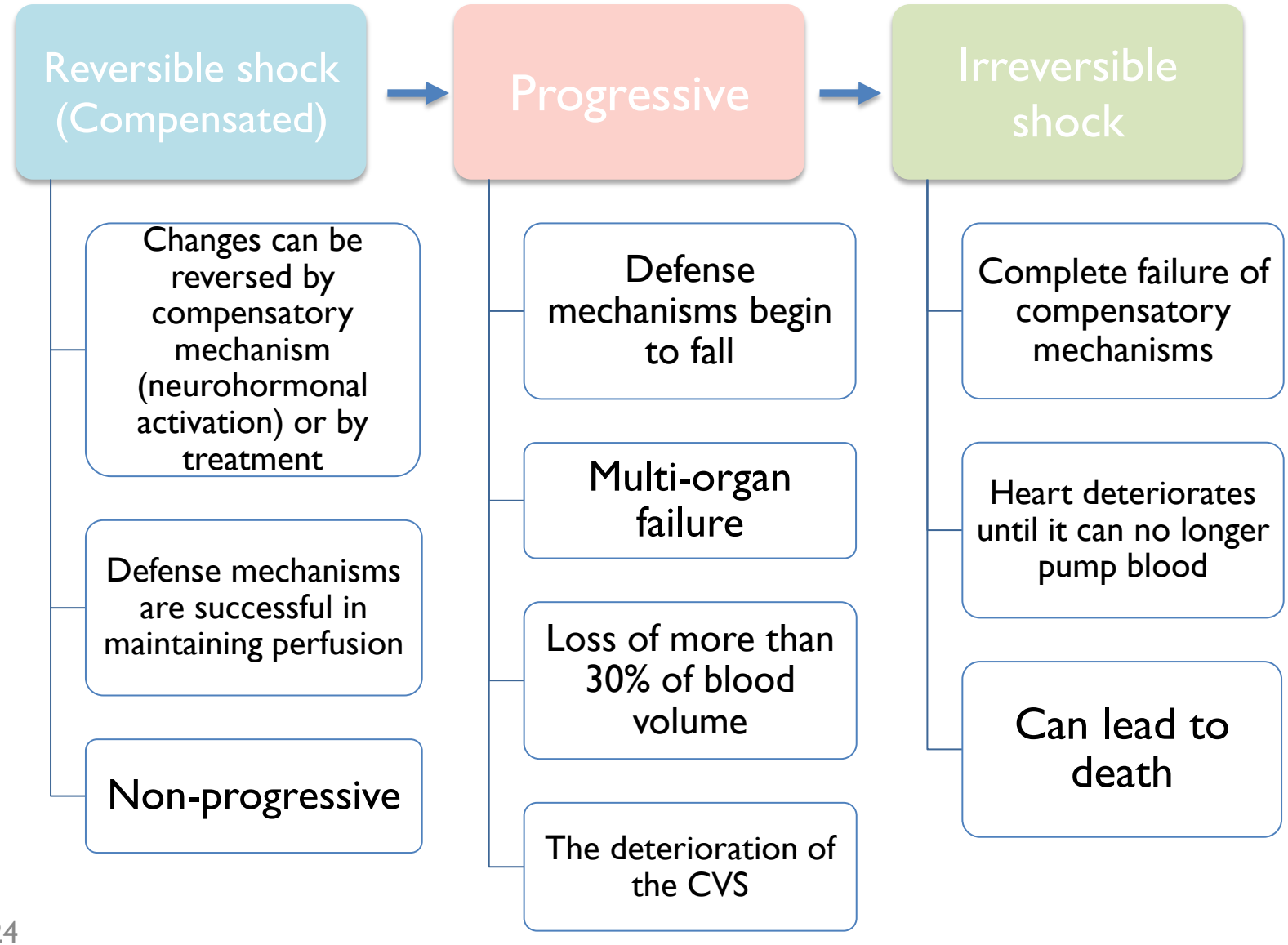
Stages of Shock



Reversible Shock
(compensated / non-Progressive)

1. Decrease in BP → Increase sympathetic responses
2. Increase sympathetic responses → Skin vaso constriction → Vasoconstriction to the kidneys → Release of epinephrine and nor-epinephrine → Increase heart rate and force of contraction
3. Hypoxia

Vasoconstriction to the kidneys lead to :

Decrease urine output → Increase renin secretion → Increase (Angiotensin II vasoconstrictor) → Increase Aldosterone → Increase Na reabsorption and H2O retention

Progressive Shock (Decompensated)

- Leads to myocardial ischemia, and a decrease in cardiac output → More decrease in Blood pressure

Decrease of mean BP below 60 mmHg

Intravascular clotting

- Decrease in blood volume → decrease in blood velocity → increase Viscosity.
- Platelets aggregate → Clot formation → Obstruction

- caused by lysosome rupture and decrease activity of mitochondria → decrease active transport and general metabolism

Cellular destruction

Build up of lactic acid

- Lead to Acidosis

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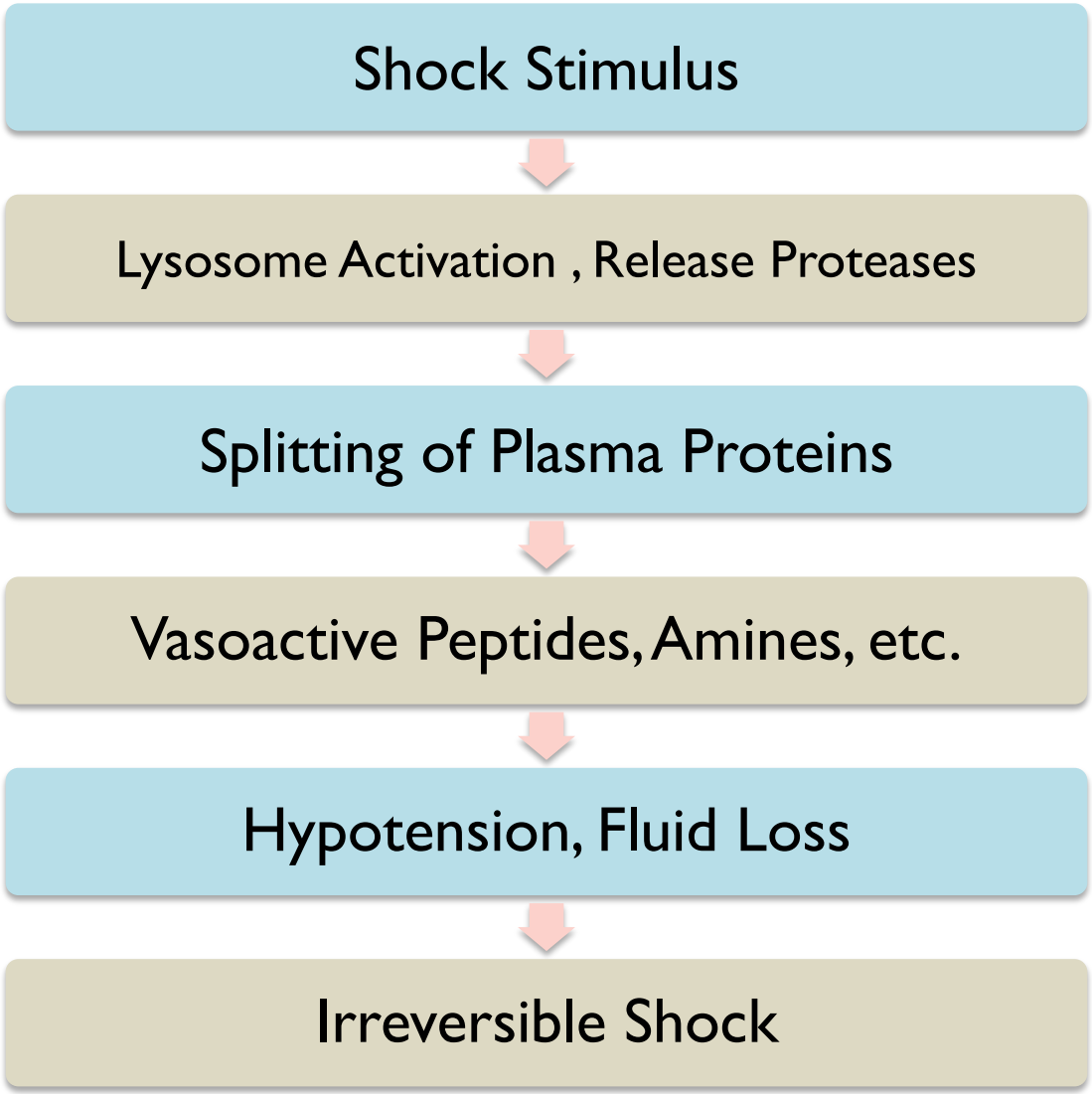
Possible Mechanism in development irreversible Shock



Summary

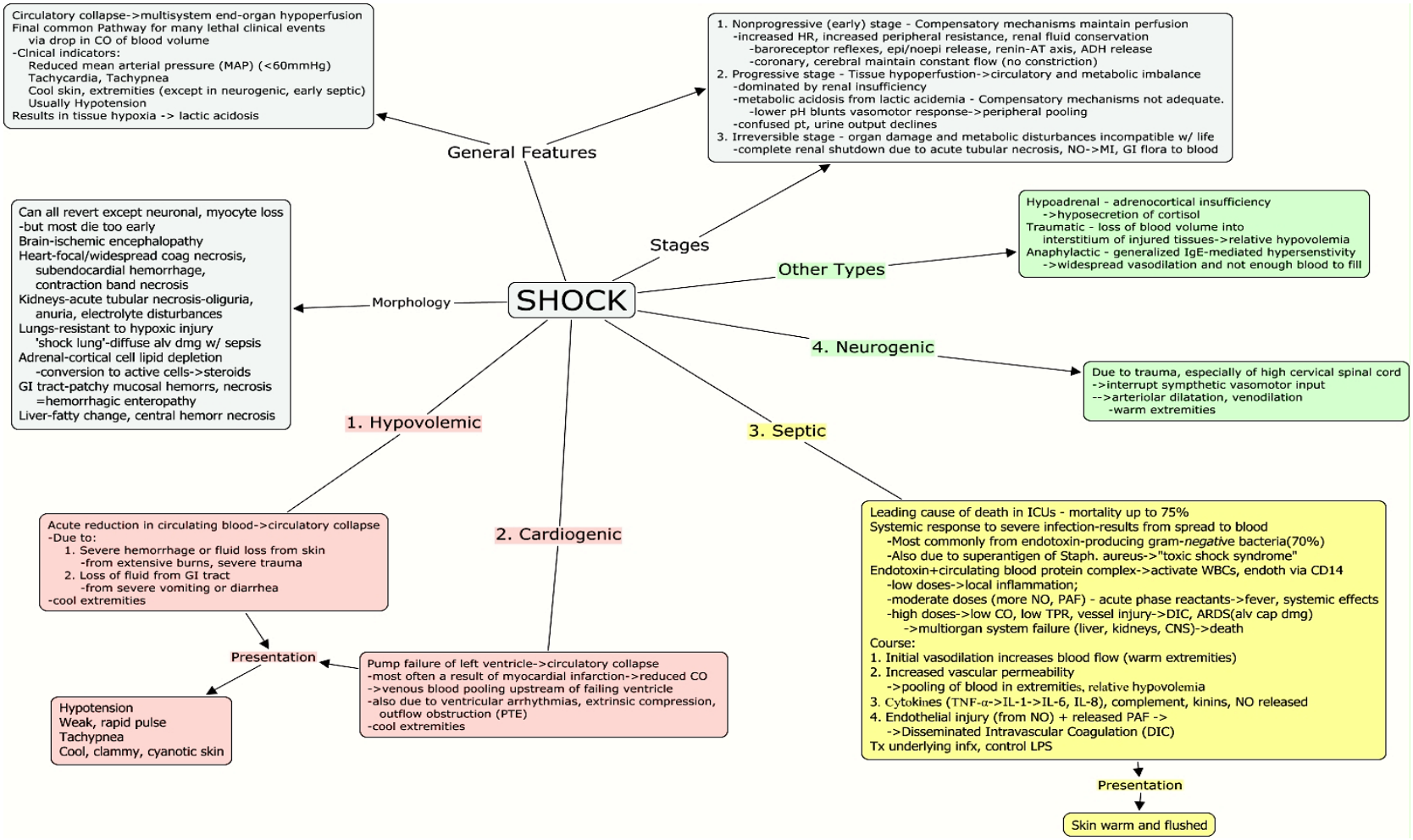
Type of shock	Insult	Physiologic effect	Compensation
Cardiogenic	Heart fails to pump blood out	↓ Cardiac output	Baroreceptors ↑ Systemic vascular resistance (SVR)
Obstructive	Heart pump well, but the outflow is obstructed	↓ Cardiac output	Baroreceptors ↑ Systemic vascular resistance (SVR)
Hemorrhagic	Heart pumps well , but not enough blood volume to pump	↓ Cardiac output	Baroreceptors ↑ Systemic vascular resistance (SVR)
Distributive	Heart pumps well , but there is peripheral vasodilation	↓ SVR	↑ Cardiac output

Hemodynamics of shock

Type of shock	Pulmonary capillary wedge pressure (PCWP) Preload	Cardiac output	Systemic vascular resistance (SVR) Afterload	Treatment
Hypovolemic shock	↓	↑	↑	IV fluid
Cardiogenic shock	↑	↓	↑	Inotropes revascularization
Distributive shock (septic, neurogenic)	↓	↑	↓	Pressors IV fluids

* Red arrow indicates primary abnormality

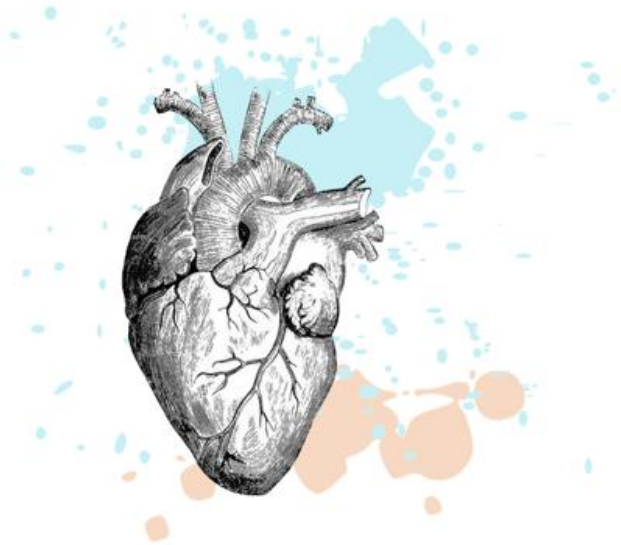
Summary


SHOCK
General Features
Circulatory collapse->multisystem end-organ hypoperfusion
Final common Pathway for many lethal clinical events
via drop in CO of blood volume
-Clnical indicators:
Reduced mean arterial pressure (MAP) (<60mmHg)
Tachycardia, Tachypnea
Cool skin, extremities (except in neurogenic, early septic)
Usually Hypotension
Results in tissue hypoxia -> lactic acidosis
Stages
1. Nonprogressive (early) stage - Compensatory mechanisms maintain perfusion
-increased HR, increased peripheral resistance, renal fluid conservation
-baroreceptor reflexes, epi/noepi release, renin-AT axis, ADH release
-coronary, cerebral maintain constant flow (no constriction)
2. Progressive stage - Tissue hypoperfustion->circulatory and metabolic imbalance
-dominated by renal insufficiency
-metabolic acidosis from lactic acidemia - Compensatory mechanisms not adequate.
-lower pH blunts vasomotor response->peripheral pooling
-confused pt, urine output declines
3. Irreversible stage - organ damage and metabolic disturbances incompatible w/ life
-complete renal shutdown due to acute tubular necrosis, NO->MI, GI flora to blood
Morphology
Can all revert except neuronal, myocyte loss
-but most die too early
Brain-ischemic encephalopathy
Heart-focal/widespread coag necrosis,
subendocardial hemorrhage,
contraction band necrosis
Kidneys-acute tubular necrosis-oliguria,
anuria, electrolyte disturbances
Lungs-resistant to hypoxic injury
'shock lung'-diffuse alv dmg w/ sepsis
Adrenal-cortical cell lipid depletion
-conversion to active cells->steroids
GI tract-patchy mucosal hemorrs, necrosis
=hemorrhagic enteropathy
Liver-fatty change, central hemorr necrosis
Other Types
Hypoadrenal - adrenocortical insufficiency
->hyposecretion of cortisol
Traumatic - loss of blood volume into
interstitium of injured tissues->relative hypovolemia
Anaphylactic - generalized IgE-mediated hypersenstivity
->widespread vasodilation and not enough blood to fill
4. Neurogenic
Due to trauma, especially of high cervical spinal cord
->interrupt sympthetic vasomotor input
-->arteriolar dilatation, venodilation
-warm extremities
1. Hypovolemic
Acute reduction in circulating blood->circulatory collapse
-Due to:
1. Severe hemorrhage or fluid loss from skin
-from extensive burns, severe trauma
2. Loss of fluid from GI tract
-from severe vomiting or diarrhea
-cool extremities
Presentation
Hypotension
Weak, rapid pulse
Tachypnea
Cool, clammy, cyanotic skin
2. Cardiogenic
Pump failure of left ventricle->circulatory collapse
-most often a result of myocardial infarction->reduced CO
->venous blood pooling upstream of failing ventricle
-also due to ventricular arrhythmias, extrinsic compression,
outflow obstruction (PTE)
-cool extremities
3. Septic
Leading cause of death in ICUs - mortality up to 75%
Systemic response to severe infection-results from spread to blood
-Most commonly from endotoxin-producing gram-negative bacteria(70%)
-Also due to superantigen of Staph. aureus->"toxic shock syndrome"
Endotoxin+circulating blood protein complex->activate WBCs, endoth via CD14
-low doses->local inflammation;
-moderate doses (more NO, PAF) - acute phase reactants->fever, systemic effects
-high doses->low CO, low TPR, vessel injury->DIC, ARDS(alv cap dmg)
->multiorgan system failure (liver, kidneys, CNS)->death
Course:
1. Initial vasodilation increases blood flow (warm extremities)
2. Increased vascular permeability
->pooling of blood in extremities, relative hypovolemia
3. Cytokines (TNF-α->IL-1->IL-6, IL-8), complement, kinins, NO released
4. Endothelial injury (from NO) + released PAF ->
->Disseminated Intravascular Coagulation (DIC)
Tx underlying infx, control LPS
Presentation
Skin warm and flushed

Physiology
OF THE CARDIOVASCULAR SYSTEM

Physiology Leaders :

Khawla Alammari
Nojood Alhaidri
Rawaf Alrawaf



Girls team :

- Atheer Alnashwan
- Asrar Batarfi
- Afnan Almalki
- Alhanouf Aljlaoud
- Deema AlFaris
- Elham Alzahrani
- Johara Almalki
- Lojain alsiwat
- Malak Alsharif
- Monirah Alsalouli
- Nora AlRomaih
- Nurah Alqahtani
- Nouf Alabdulkarim
- Nora Albusayes
- Nora Alsomali
- Norah Alakeel
- Reem Alageel
- Rawan Aldhuwayhi
- Reham Al-Obaidan
- Samar AlOtaibi
- Shamma Alsaad

Boys team :

- Abdullah Aljaafar
- Omar Alotaibi
- Abdulrahman Albarakah
- Adel Alshehri
- Abdulaziz Alghanaym
- Abdulmajeed Alotaibi
- Khalil Alduraibi
- Hassan Albeladi
- Omar Alshehri
- Saleh Alshawi
- Abdulaziz Alhammad
- Faisal Alabdulatif
- Abdulnasser Alwabel
- Saad Almutairy