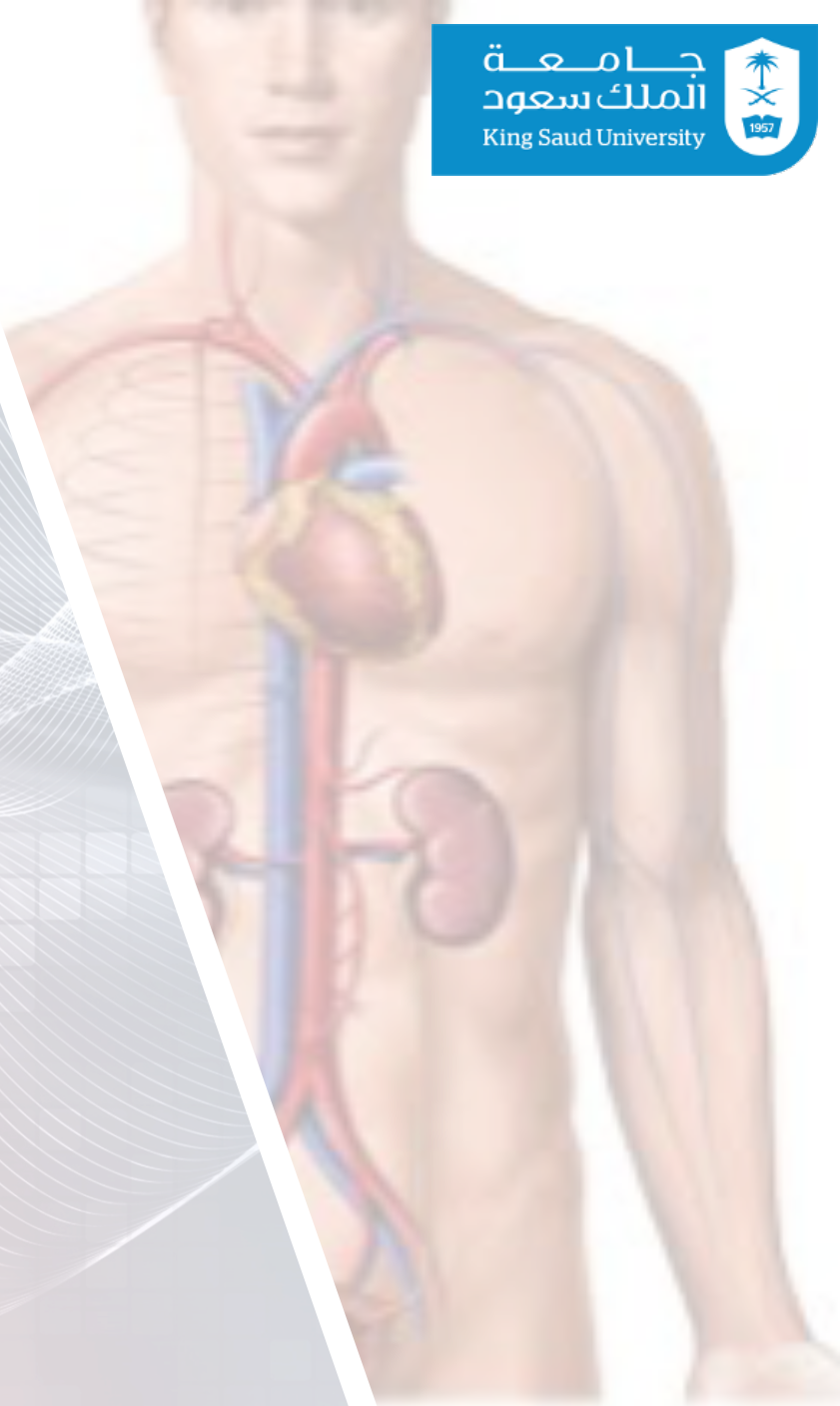
Cardiovascular Physiology

Shock



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Shock

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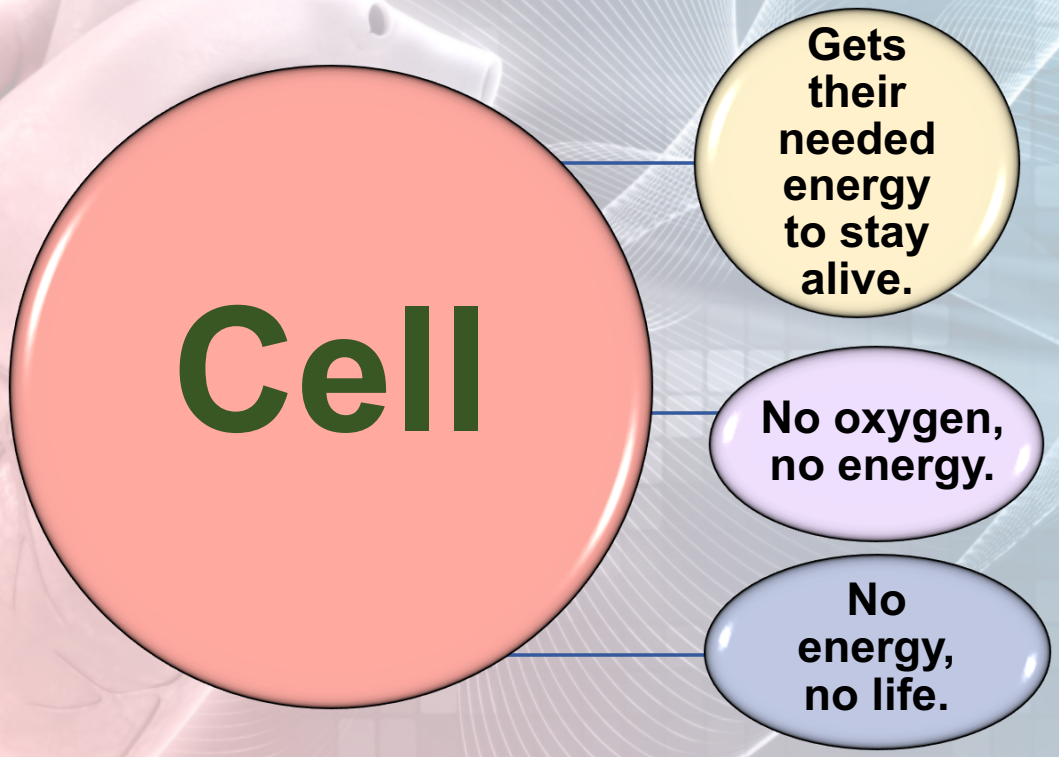
Lecture Outcomes

- To describe different types of Shock.
- To understand the pathophysiology of Shock.
- To define different stages of Shock.
- To understand different compensatory mechanisms in response to Shock.
- To define different mechanisms responsible for Irreversible Shock.

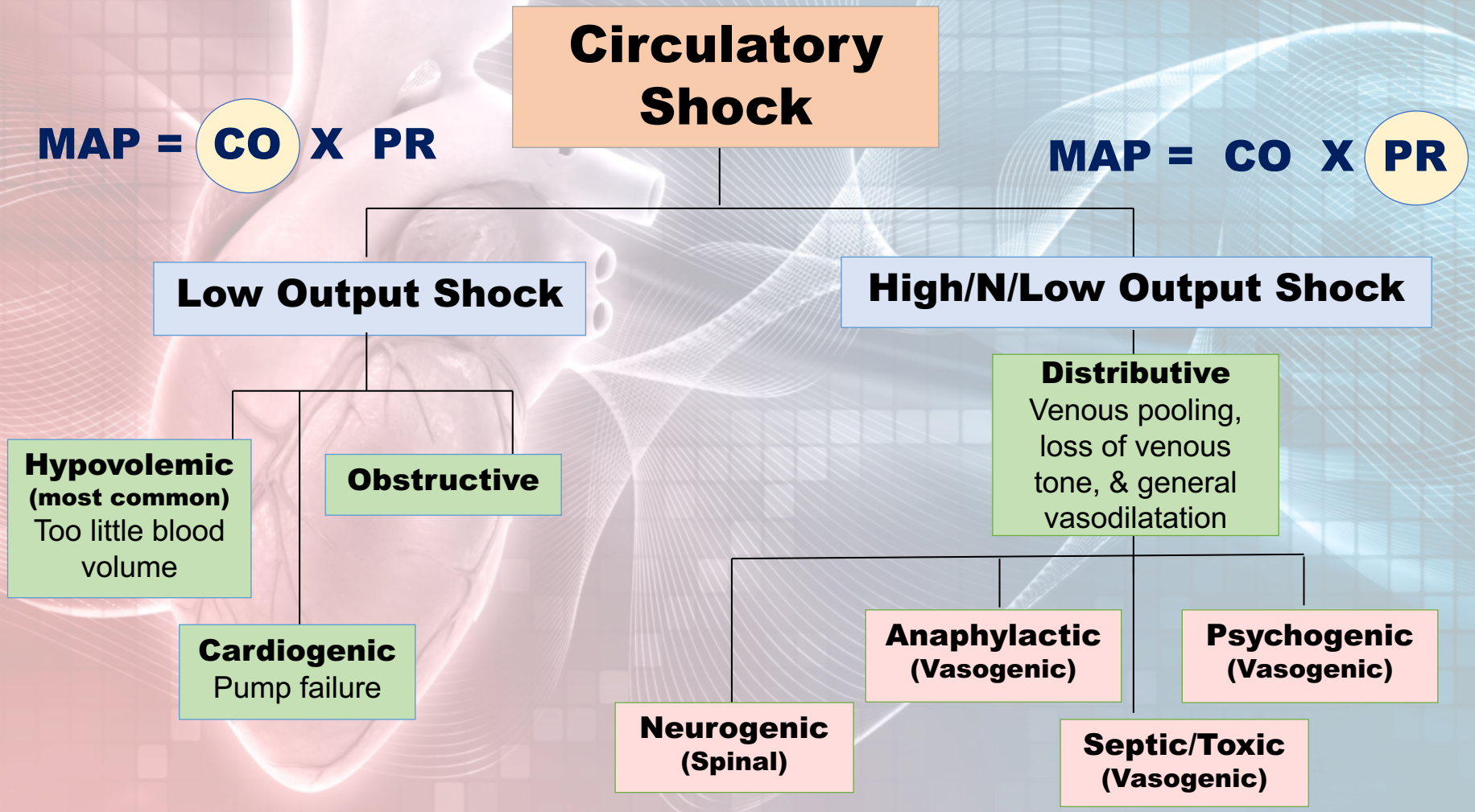
Basic Unit of Life



What is Shock?

- Any condition in which circulatory system is unable to provide adequate circulation & tissue perfusion.
- Results in failure to deliver oxygen to the tissues & vital body organs relative to its metabolic requirements, leading to **organ dysfunction** & **cellular damage**.
- Defined as **Circulatory Shock**.
- If not corrected quickly, it may lead to irreversible shock & death.

Types of Circulatory Shock



Hypovolemic Shock

Low Cardiac Output

- **Low CO due to:**
  - Inadequate blood/plasma volume (loss of <15 - >40% or <750mL - >2L).
  - Reduced venous return (preload.)
- **Causes:**
  - Blood loss/ Hemorrhage: (commonest)
    - Internal or external.
  - Fluid/plasma loss:
    - Vomiting, diarrhea, burn, excess sweating, dehydration, trauma.

MAP = CO X PR

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Cardiogenic Shock

Low Cardiac Output

- **Low CO due to:**
  Inability of cardiac muscle to pump adequate blood in presence of a normal blood volume.

  Almost associated with elevated ventricular filling pressure (Rt/Lt/or Both).

- **Causes: Deterioration of cardiac function**
  - **Myocardial:**
    Acute Myocardial Infarction (Most common.), Myocarditis, Cardiomyopathy.
  - **Mechanical:**
    Acute valvular dysfunction, e.g. rupture of papillary muscle post MI.
  - **Arrhythmogenic:**
    Sustained Arrhythmias, e.g. heart block, ventricular tachycardia.
  - **? Obstructive:**
    Pulmonary embolism, Cardiac tamponade.
- Is associated with **loss of > 40%** of LV myocardial function.
- **Mortality rate is high, 60-90%.**

MAP = CO X PR

Obstructive Shock

Low Cardiac Output

- **CO is reduced by vascular obstruction:**

- Obstruction of venous return:

e.g. Vena Cava Syndrome (usually neoplasms).

- Compression of the heart:

e.g. hemorrhagic pericarditis → cardiac tamponade.

- Obstruction of the outflow of the heart:

Aortic dissection.

Massive pulmonary embolism.

Pneumothorax.

Distributive Shock

High/Normal Cardiac Output

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

Distributive Shock

High/Normal Cardiac Output

- **Septic/ Toxic/ Endotoxic Shock:**
  - Bacterial endotoxin triggers peripheral vasodilatation & endothelial injury.
  - Hyper-dynamic state.

- **Psychogenic shock:**
  - Simple fainting (syncope.)
  - Caused by stress, pain, or fright.
  - ↓ HR & vessels dilate.
  - Brain becomes hypo-perfused.
  - Loss of consciousness.

Distributive Shock

Low Cardiac Output

- **Anaphylactic shock:**
  - Massive & generalized allergic reaction.
  - IgE- Mediated hypersensitivity.
  - Histamine triggers peripheral vasodilation & ↑ capillary permeability.
  - Can lead to low cardiac output distributive shock.




- **Neurogenic/ Spinal Shock (venous pooling):**
  - Loss or drop in vasomotor (vascular) tone/ spinal cord injury.
  - Generalized peripheral vasodilation.
  - Blood volume remains normal.
  - CO is severely reduced as blood is pooled in peripheral veins.. (Capacity of blood ↑, & venous return ↓.)
  - Behaves like hypovolemic shock.

Pathophysiology of Shock

Metabolic Changes & Cellular Response to Shock

1. **Reduce capillary perfusion:**

→ Spasm of pre/post capillary sphincters**.**

→ hypoxic tissue damage, (oxidative stress.)

→ anaerobic metabolism (anaerobic glycolysis.)

→ lactic acid production.

→ **metabolic acidosis (intracellular acidosis)**.

→ **Failure of Na^+/K^+ pump** (↑ [Na^+] & [Ca^{2+}]).

→ **Lysosomes, nuclear membranes & mitochondrial breakdown**.

Metabolic Changes & Cellular Response to Shock

2. **After 3 - 5 hrs 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 → vasodilation + ↓ HR
   (vasomotor center .. sympathetic)
   → 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.**

Compensatory Mechanisms to Shock

Physiological reaction in response to ↓ BP will lead to the following in order to ↑ BP:

- ↑ HR & myocardial contractility → ↑ CO .
- Vasoconstriction → ↑ Preload & filling pressure.
- ↑ Blood volume.
- ↑ Vascular compliance.
- Restoration of tissue perfusion.

Compensatory Mechanisms to Shock

1. Stimulation of Sympathetic Nervous System through:

- **Baroreceptors reflex** mechanism.
- Acidosis stimulates **chemoreceptors reflex mechanism** → sympathetic stimulation.

❑ **Leads to ↑ HR, ↑ Myocardial contractility, Vasoconstricion, & ↑ BP.**

2. Activation of Renin-Angiotensin System:

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

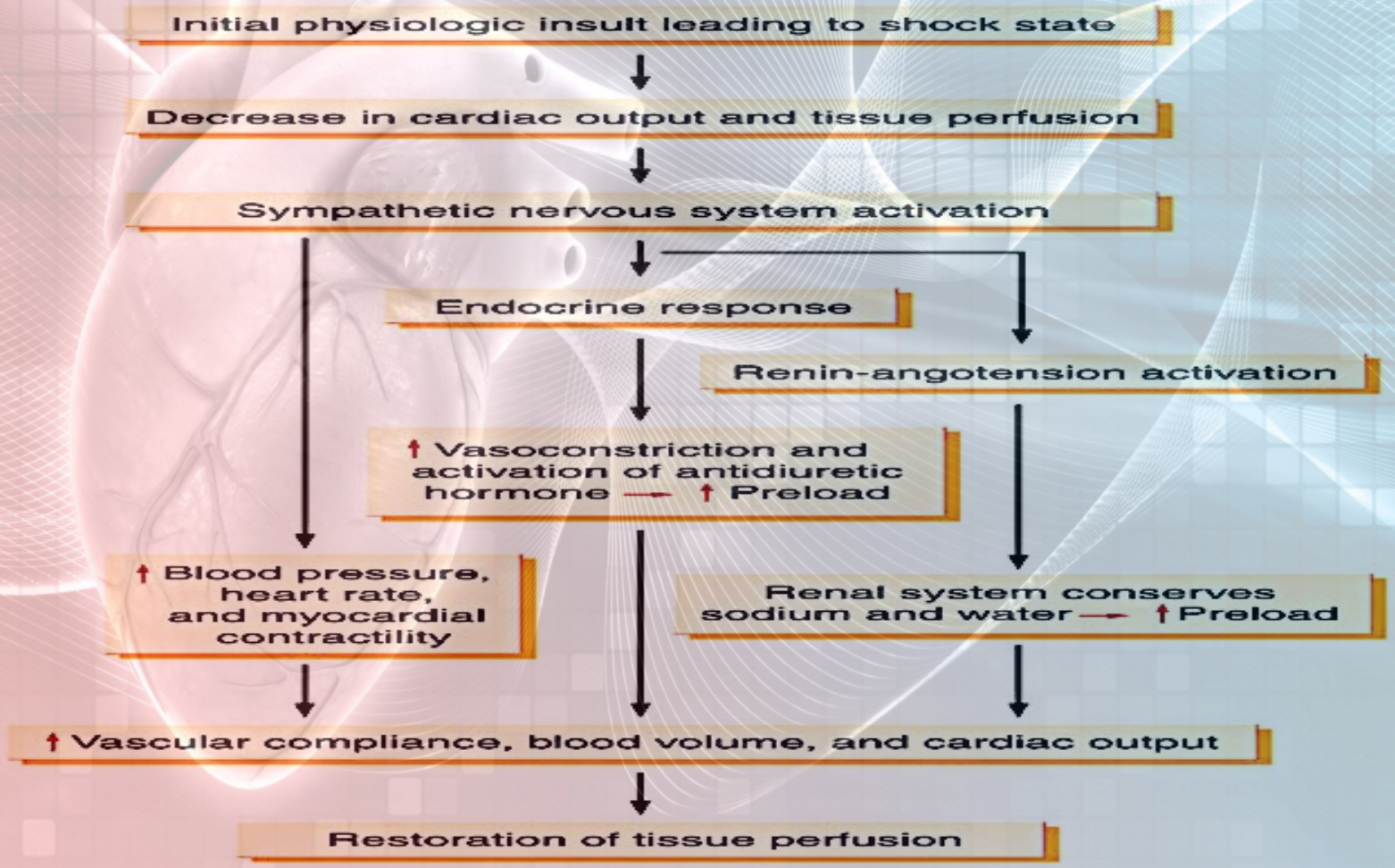
3. Stimulation of ADH (vasopressin):

- Water retention, vasoconstriction & thirst stimulation.

4. Synthesis of Plasma Proteins: (3-4 days)

5. Fluid- shift mechanism:

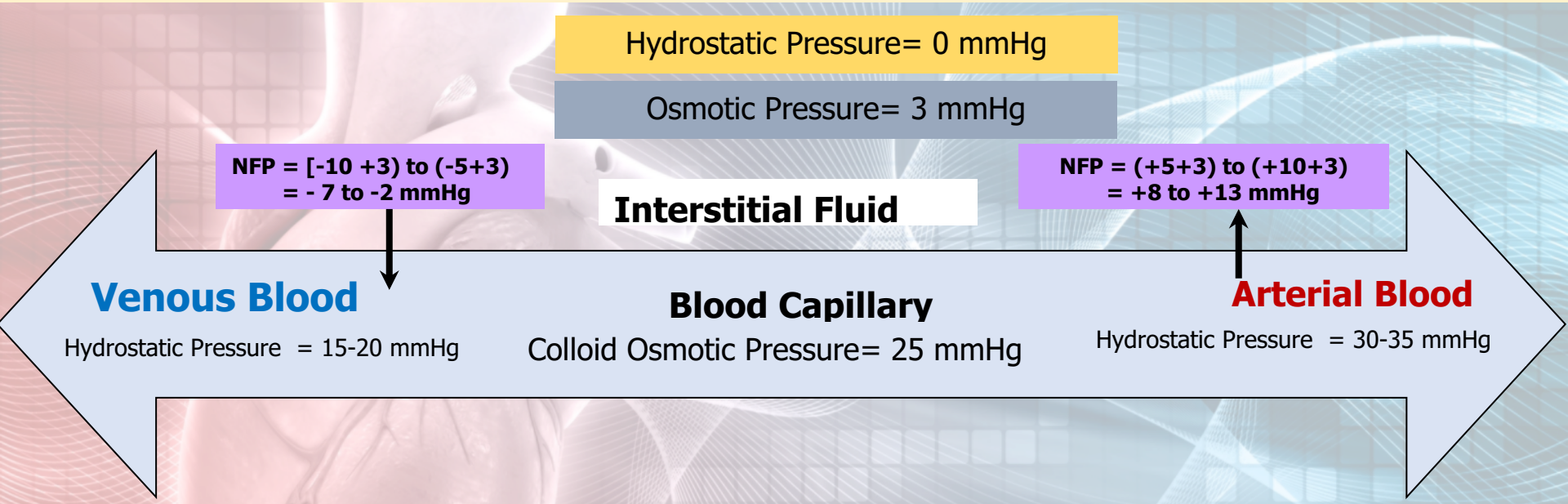
Compensatory Mechanisms



Fluid- Shift Mechanism in Shock

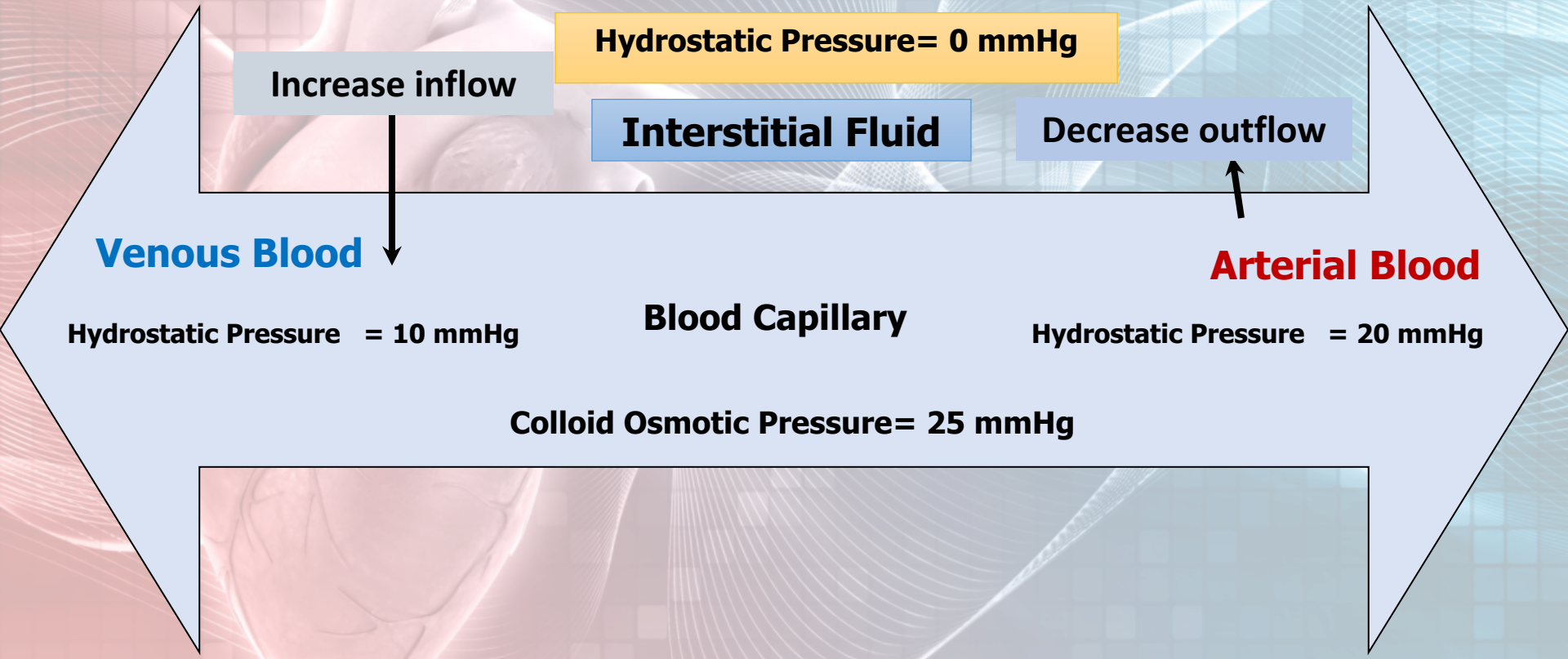
- In shock, the hydrostatic pressure decreases & oncotic pressure is constant, as a result:
  - The fluid exchange from the capillary to the extracellular space decreases.
  - The fluid return from the extracellular space to the capillary increases.
- This will lead to an increase in the blood volume & the BP in order to help in compensating shock situation.

In Normal Microcirculation



- **At arterial end:**
  - Water moves **out** of the capillary with a NFP of +8 to +13 mmHg.
  - Hydrostatic pressure dominates at the arterial end & a net sum of pressure forces (blood hydrostatic + IF osmotic pressures) flow fluid out of the circulation.
- **At venous end:**
  - Water moves **into** the capillary with a NFP of -7 to -2 mmHg.
  - Oncotic pressure dominates at the venous end & a net sum of pressure forces (blood osmotic + IF hydrostatic pressures) flow fluid into the bloodstream.

Fluid- Shift Mechanism In Shock



Stages of Shock

- **Reversible shock: (Compensated)**
  - Changes can be reversed by compensatory mechanism (neurohormonal activation) or by treatment.
  - Defense mechanisms are successful in maintaining perfusion.
  - Non-progressive.
- **Progressive:**
  - Defense mechanisms begin to fall.
  - Multi-organ failure.
- **Irreversible shock:**
  - Complete failure of compensatory mechanisms.
  - Can lead to death.

Possible Mechanisms that Lead to Developing Irreversible Shock

Shock Stimulus

↓

Lysosomal Activation, Release Proteases

↓

Splitting of Plasma Proteins

↓

Vasoactive Peptides, Amines, etc.

↓

Hypotension, Fluid Loss

↓

Irreversible Shock

Signs and Symptoms:
Hypovolemic Shock

- Sustained Hypotension… (? ≤ 85/40 mmHg for 30 min.)
- Tachycardia… sensed by Baroreceptors in compensation to the ↓ MAP.
- Rapid, weak, & thready pulse… (? 140/min).
- Intense thirst.
- Tachypnea (rapid respiration)… sensed by Chemoreceptors in compensation for hypoxia.
- Restlessness… due to hypo-perfusion.
- Cold, pale skin… due to hypo-perfusion.
- Oliguria (low urine output)/ Anuria (no urine output).
- Blood test: Lactic acidosis.

Signs, Symptoms & Treatment:
Hypovolemic Shock

	Class I	Class II	Class III	Class IV
Blood Loss	< 750	750-1500	1500-2000	> 2000
% Blood Vol.	< 15%	15 – 30%	30 – 40%	> 40%
Pulse	< 100	**> 100**	> 120	> 140
Blood Pressure	Normal	Normal	**Decreased**	**Decreased**
Pulse Pressure	Normal	**Decreased**	**Decreased**	**Decreased**
Resp. Rate	14 – 20	**20 – 30**	**30 – 40**	**> 40**
UOP	> 30	**20 – 30**	**5 – 15**	**negligible**
Mental Status	sl. Anxious	mildly anx	**confused**	**lethargic**
Fluid	crystalloid	crystalloid	**blood**	**blood**

Signs and Symptoms:
Cardiogenic Shock

Similar signs & symptoms to that of hypovolemic shock.

Congestion of lungs & viscera: (Chest X-Ray -CXR)

- Interstitial pulmonary edema.
- Alveolar edema.
- Cardiomegaly.

Signs and Symptoms:
Septic Shock

- Patient flushed & warm: due to his hyper-dynamic state.

Thank You