MED 522 B Lecture 5: The Pulmonary Circulation

The low-pressure pulmonary circulation, pulmonary embolism and blood clots, pulmonary hypertension, and the strain on the right heart.

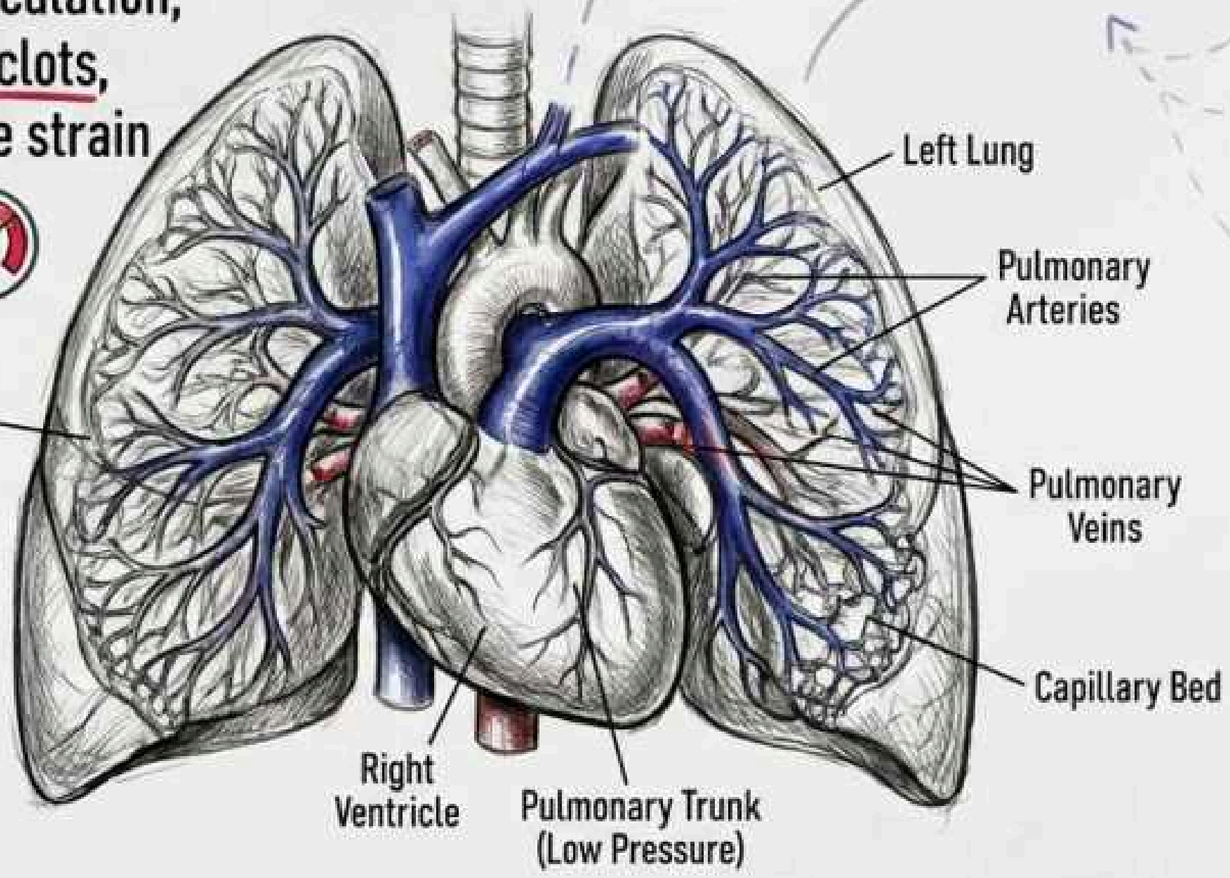
STRAIN

$$\Delta P = F \times R$$

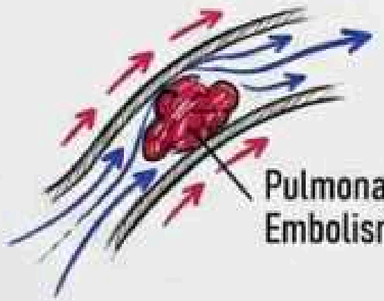
$$Q = \frac{V}{A}$$

$$PVR = \frac{MPAP - MLAP}{CO}$$

$$R = \frac{8\eta L}{\pi r^4}$$



Increased Resistance (R) → High Pressure (ΔP)



$Q = \frac{\Delta P}{R}$

The Low-Pressure System

¶ 5.1

$P = Q \times R$

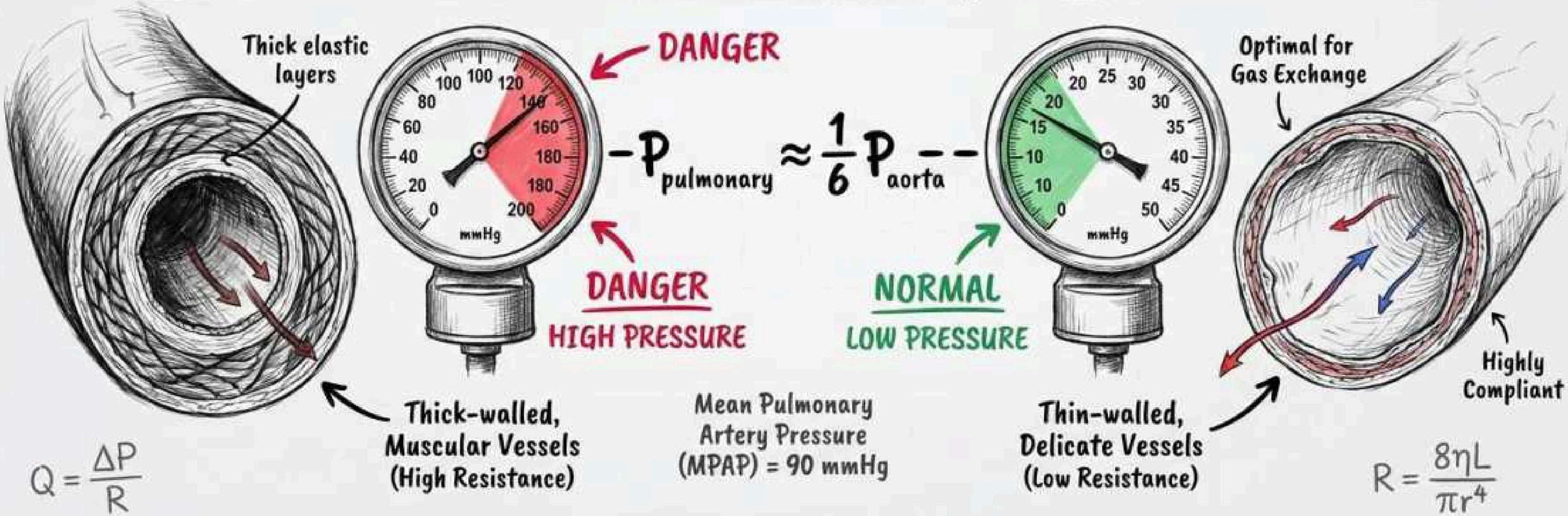
The lungs receive 100% of the right heart's output—about 5 litres of blood every minute. It is a low-pressure, low-resistance system with thin-walled vessels built specifically for optimal gas exchange.

$R = \frac{8\eta L}{\pi r^4}$

Systemic Circulation

Mean Pulmonary Artery Pressure (MPAP) = 15 mmHg
Mean Arterial Pressure (MAP) = 90 mmHg

Pulmonary Circulation



$Q = \frac{\Delta P}{R}$

$R = \frac{8\eta L}{\pi r^4}$

Hypoxic Vasoconstriction: Local Adaptation vs. Global Destruction

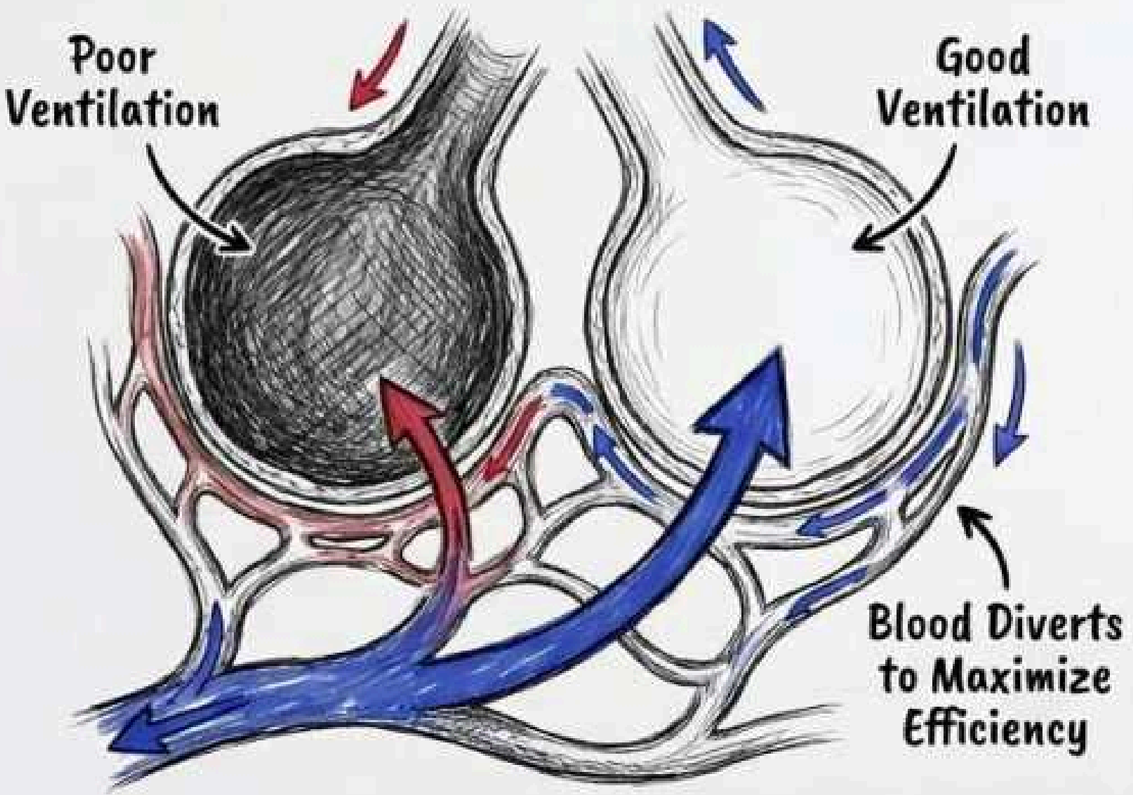
¶ 5.2

$R_{pulm} \uparrow\uparrow$ when $P_{O2} \downarrow\downarrow$

Lung vessels uniquely narrow when nearby oxygen falls,
Lung vessels uniquely narrow when nearby oxygen falls,
diverting blood to better-ventilated areas.

$\Delta P_{pulm} \uparrow\uparrow = Q \times R_{pulm} \uparrow\uparrow$

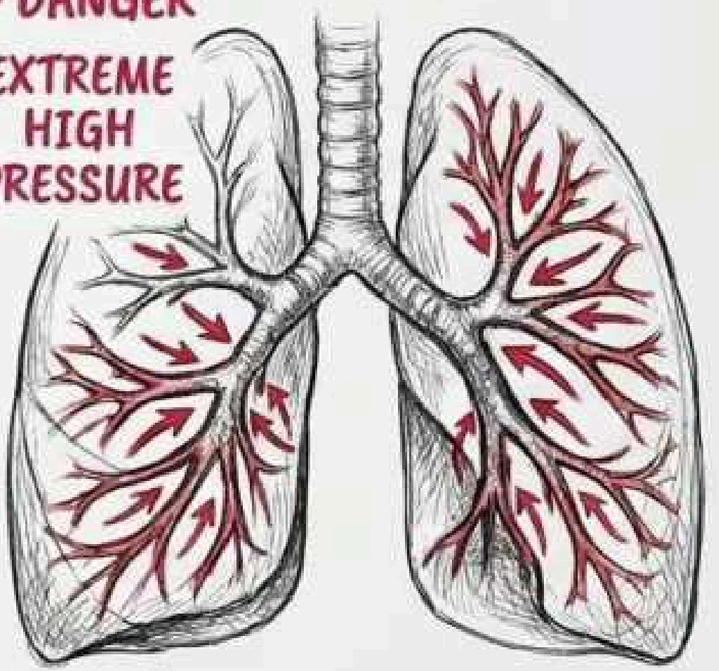
Adaptive Locally



Destructive Globally



DANGER
EXTREME HIGH PRESSURE



Widespread Narrowing in Advanced Disease or High Altitude

$\Delta P_{pulm} \uparrow\uparrow = Q \times R_{pulm} \uparrow\uparrow$

The Migration of a Clot: DVT to PE

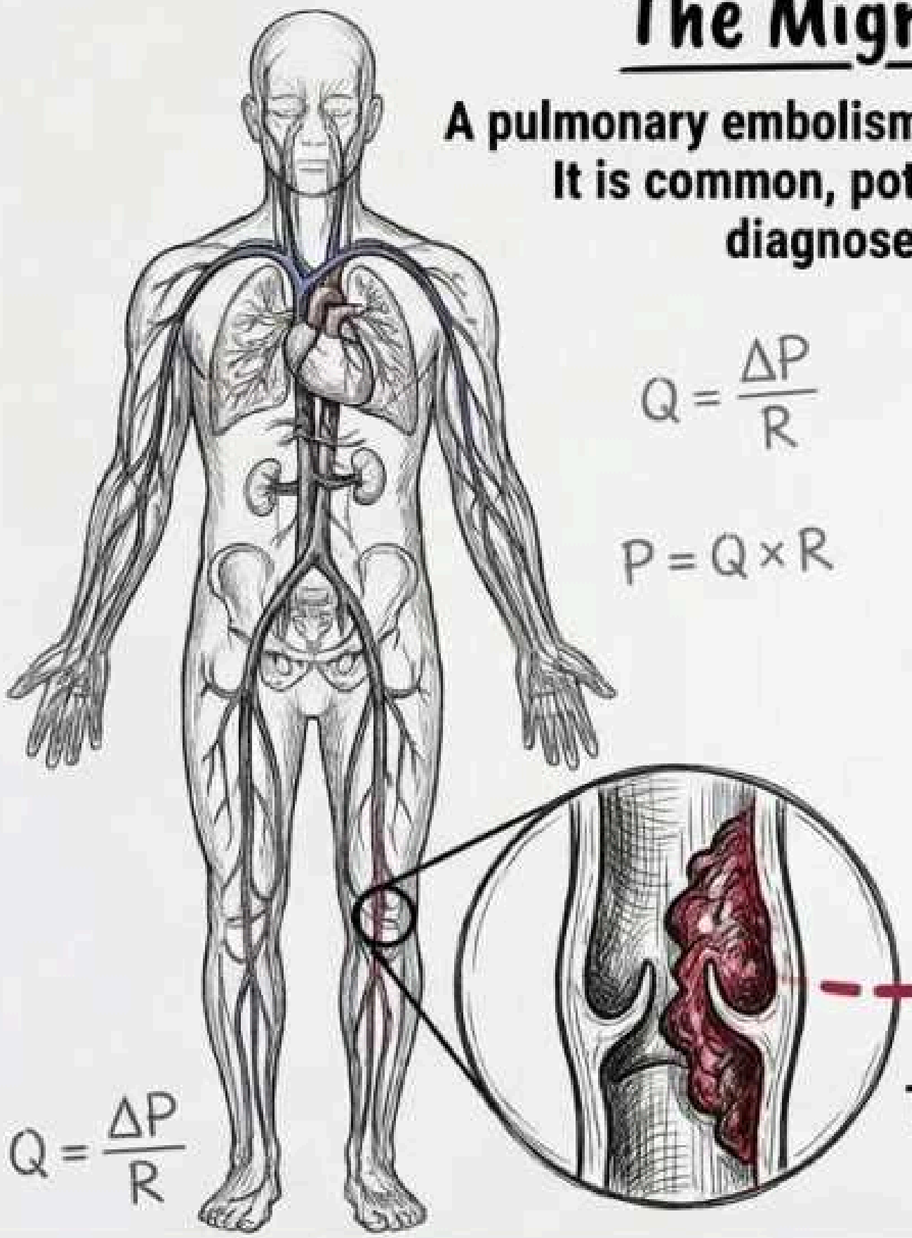
¶ 5.3

A pulmonary embolism occurs when a clot lodges in a pulmonary artery. It is common, potentially fatal, and one of the most important diagnoses not to miss in a breathless patient.

$$R = \frac{8\eta L}{\pi r^4}$$

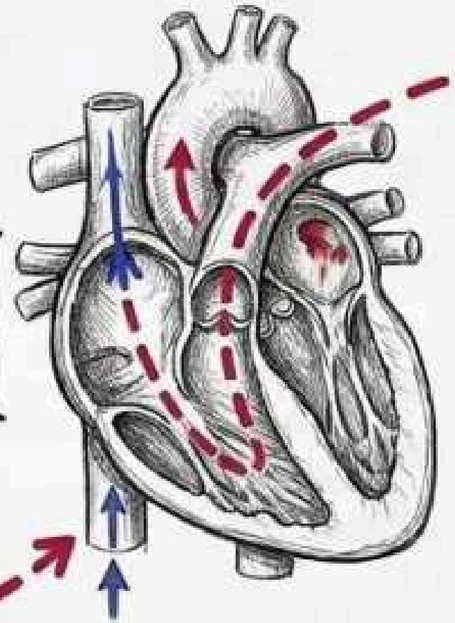
$$Q = \frac{\Delta P}{R}$$

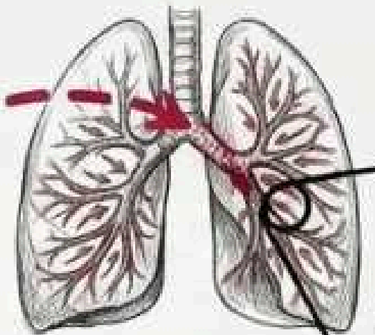
$$P = Q \times R$$



Deep Vein Thrombosis (Origin)

flight path





Pulmonary Embolism (Destination)



Pulmonary Embolism (Destination)

$$R = \frac{8\eta L}{\pi r^4}$$

$$P = Q \times R$$

$$R = \frac{8\eta L}{\pi r^4}$$

$$Q = \frac{\Delta P}{R}$$

Virchow's Triad: The Three Pillars of Venous Thrombosis

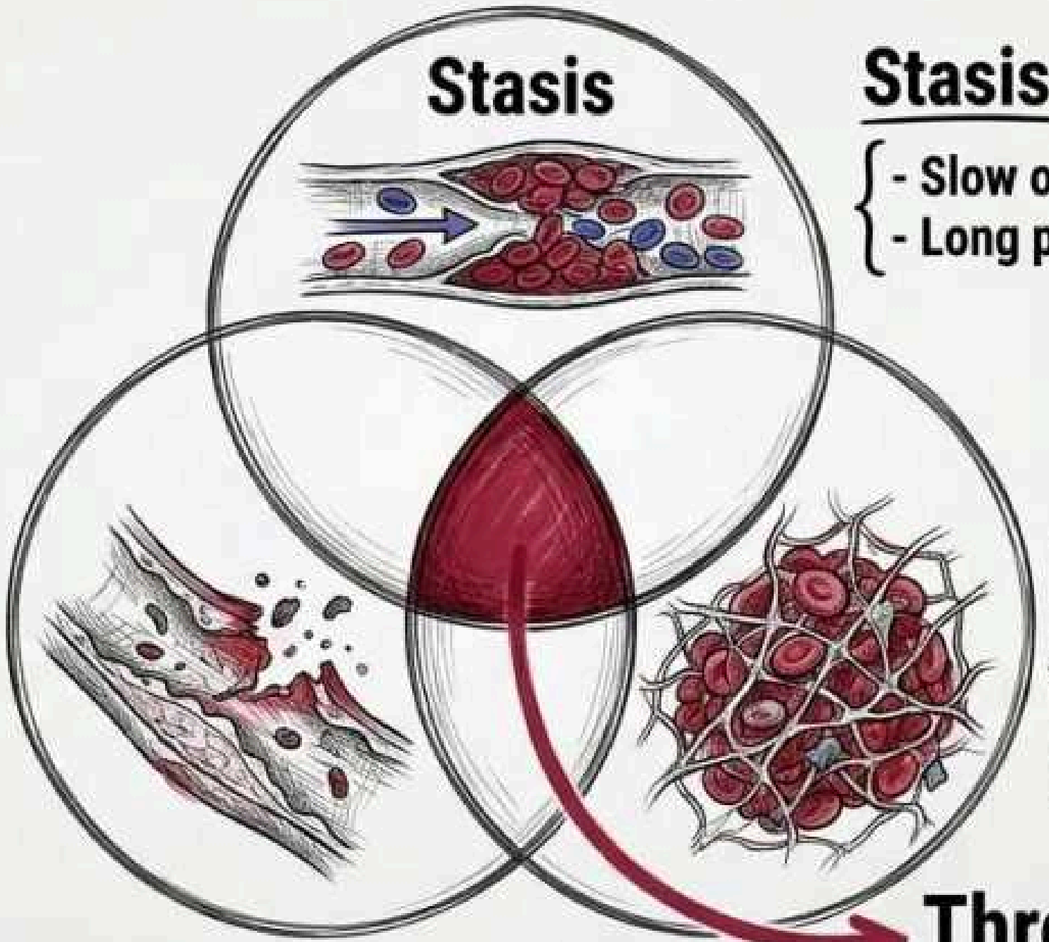
¶ 5.4

Identified in the nineteenth century by German pathologist Rudolf Virchow, these three factors favor blood clotting in veins.

$$R = \frac{8\eta L}{\pi r^4}$$

$$Q = \frac{\Delta P}{R}$$

$$P = Q \times R$$



Stasis

- Slow or stagnant blood flow
- Long periods of immobility

Vessel Injury

- Damage to the vessel wall
- Recent surgery

Hypercoagulability

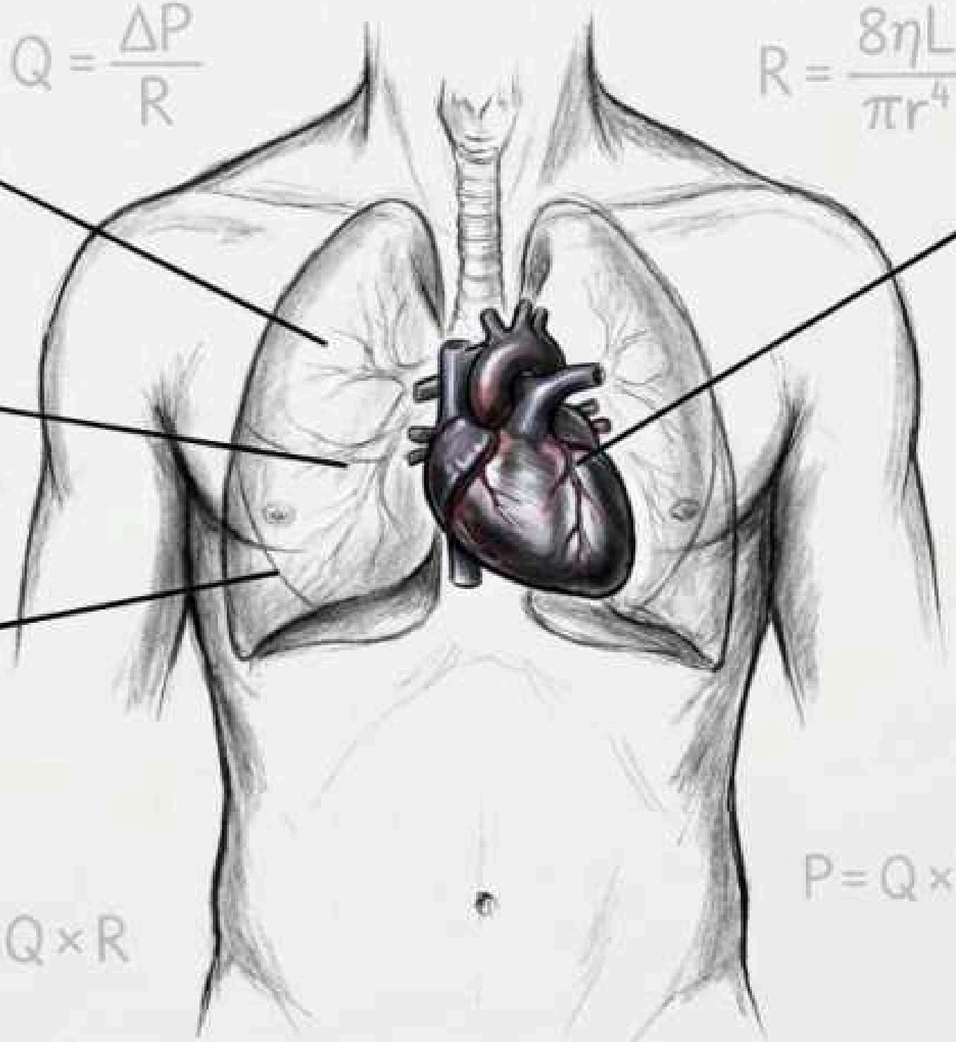
- Increased tendency to clot
- Cancer & Pregnancy
- Oestrogen-containing medicines
- Inherited clotting disorders

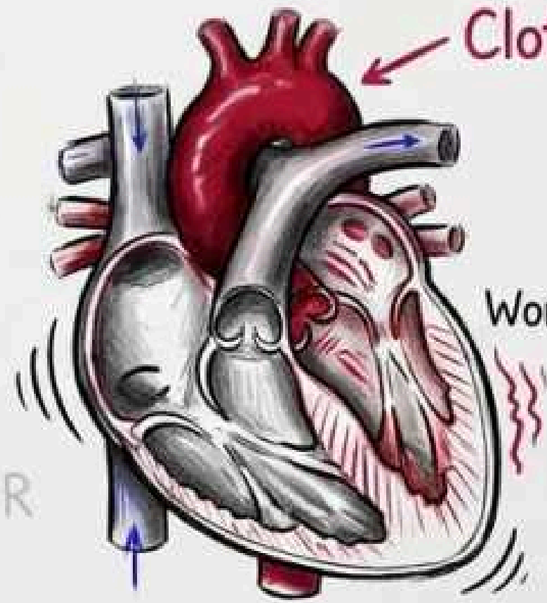
Clinical Presentation: From Breathlessness to Shock

¶ 5.5

Symptoms range from mild breathlessness to complete collapse.

- Sudden breathlessness
- Pleuritic chest pain (worsens on breathing in)
- Coughing blood
- Fast heart rate (tachycardia)





$$Work = \Delta P \times \Delta V$$

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

Bayesian Logic in PE Diagnosis

¶ 5.6

Because symptoms overlap with other conditions, doctors rely on the probability reasoning of Medicine 515 B.

Clinical Score
(Pre-test probability)

Low Probability

D-Dimer
Blood Test

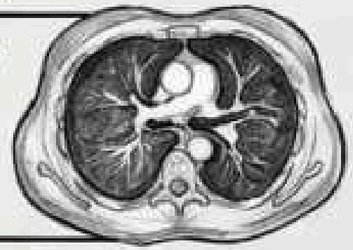


Normal

Embolism Ruled Out

High Probability OR
Elevated D-dimer

Computed Tomography
of Pulmonary Arteries
(CTPA)



Embolism Confirmed
or Excluded

Halting Growth, Dissolving Clots, Preventing Recurrence

¶ 5.7

$$Q = \frac{\Delta P}{R}$$

The body gradually dissolves existing clots; medicine focuses on preventing growth and recurrence.

$$P = Q \times R$$

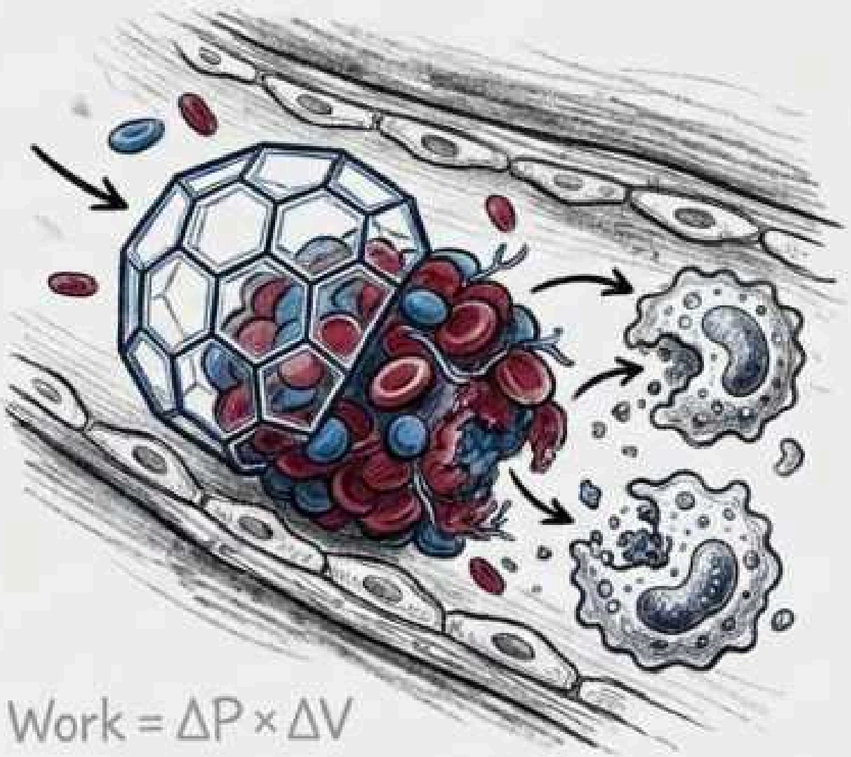
$$\text{Work} = \Delta P \times \Delta V$$

1. Prevention (Hospital Focus)



Has prevented many deaths in at-risk patients.

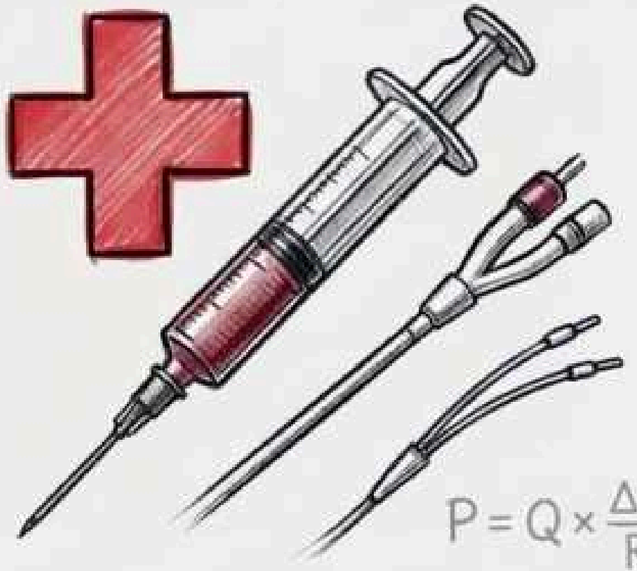
2. Standard Care



$$\text{Work} = \Delta P \times \Delta V$$

$$Q = \frac{\Delta P}{R}$$

3. Life-Threatening Cases



$$P = Q \times \frac{\Delta P}{R}$$

Clot-dissolving drugs (thrombolytics) or physical surgical extraction.

Pressure Backing Up: The Four Sources of Pulmonary Hypertension

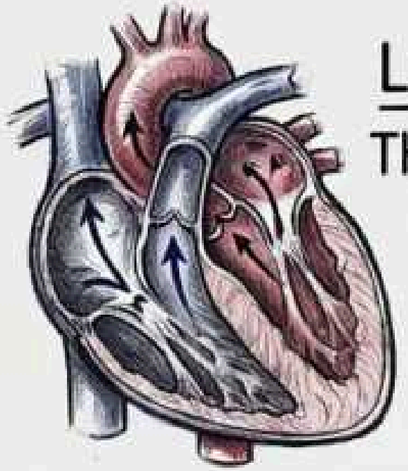
¶ 5.8

$Q = \frac{\Delta P}{R}$

Pulmonary hypertension (abnormally high pressure in pulmonary arteries) arises from multiple distinct pathways.

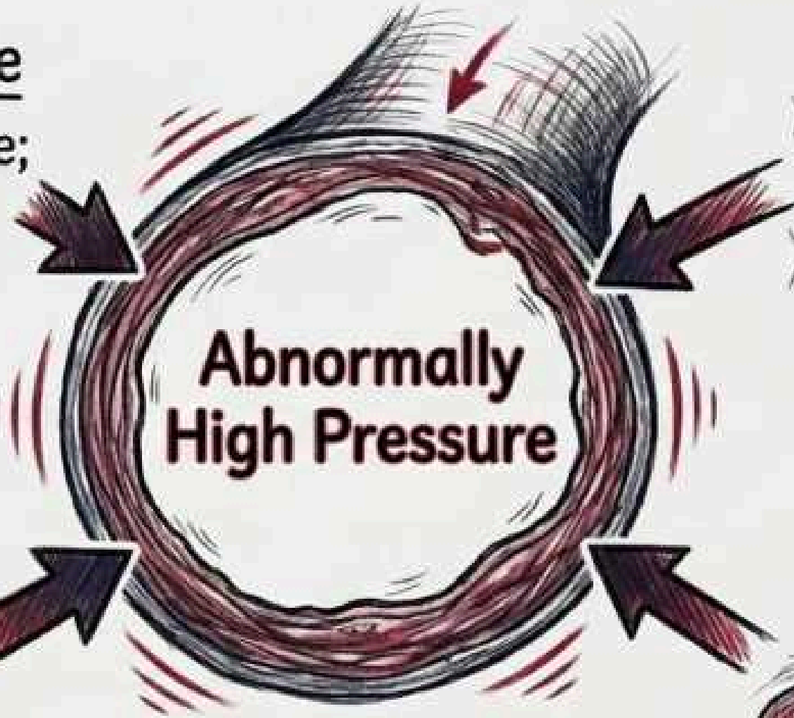
$P = Q \times R$

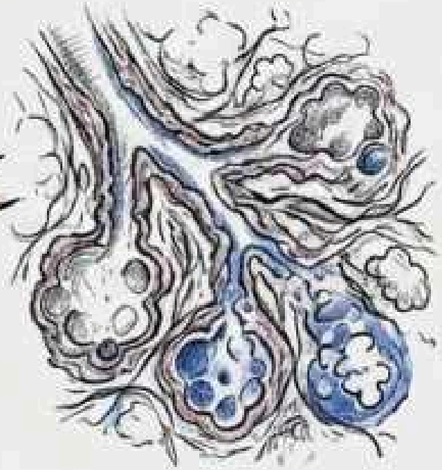
$Work = \Delta P \times \Delta V$



Left Heart Disease

The commonest cause; pressure backs up from a failing left side.





Chronic Lung Disease

Triggered by prolonged low oxygen levels.

$P = Q \times R$

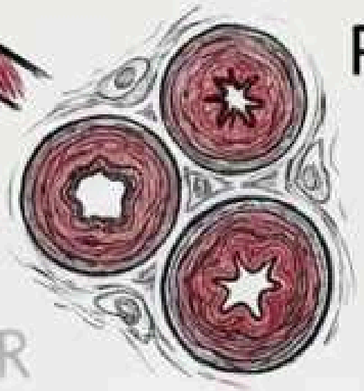


Chronic Clots

Long-standing clots that never fully dissolved.

$R = \frac{8\eta L}{\pi r^4}$

$P = Q \times R$



Pulmonary Arterial Hypertension

A rare disease of the pulmonary arteries themselves.

Cor Pulmonale: The Strain on the Right Heart

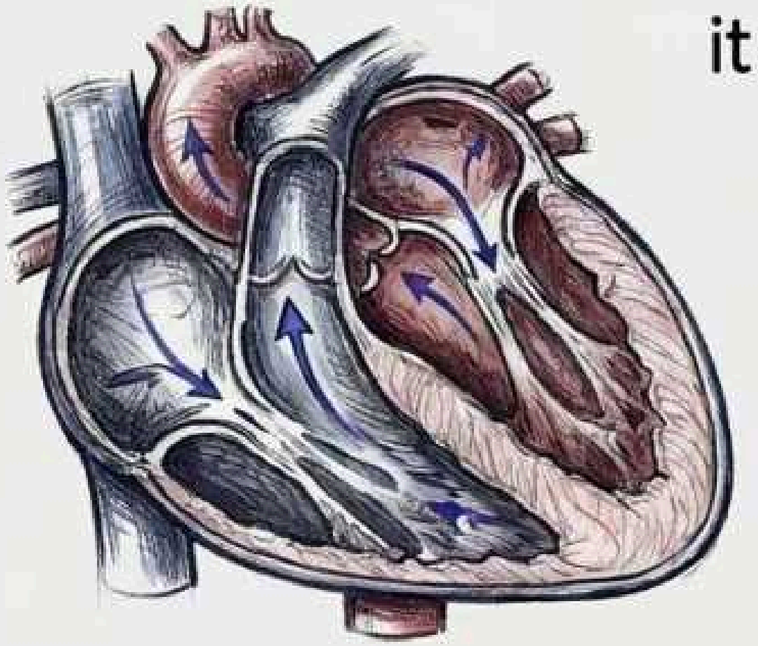
¶ 5.9

The right ventricle is built for volume, not pressure.
When strained by lung disease (Cor Pulmonale),
it thickens and ultimately fails.

$$PVR = \frac{\Delta P}{Q}$$

$$Work = P \times V$$

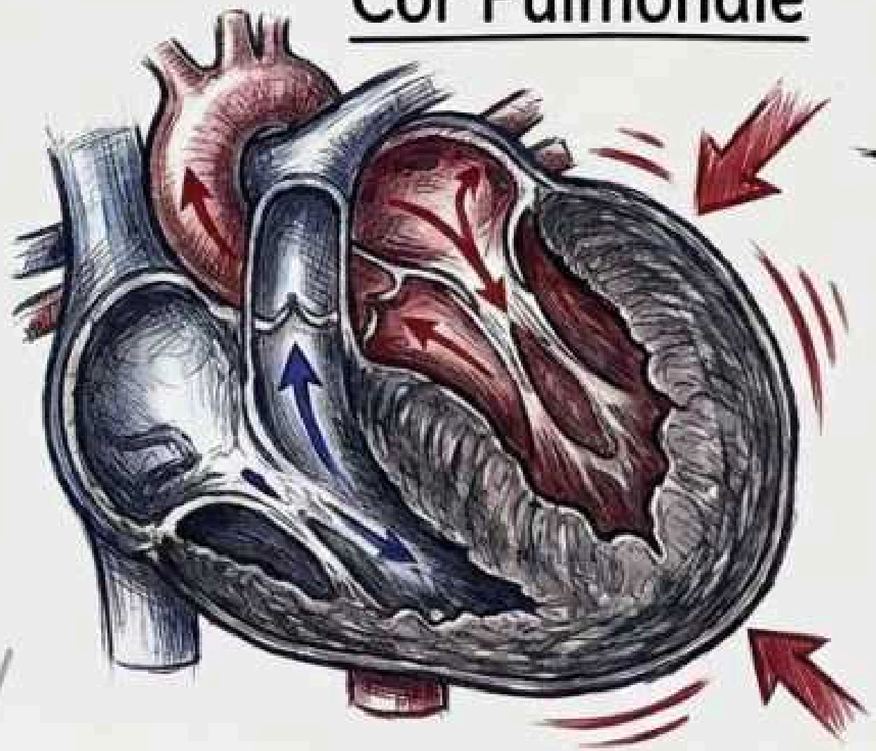
Healthy

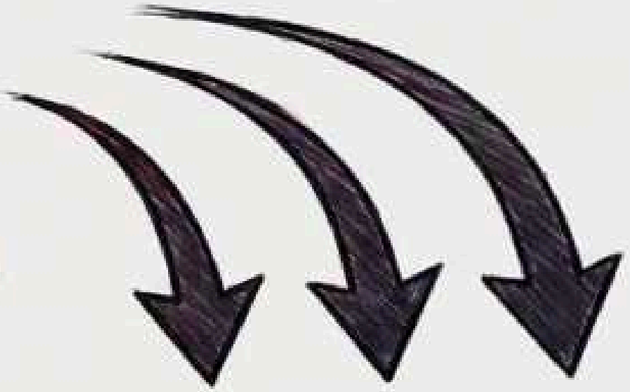


$$PVR = \frac{\Delta P}{Q}$$

$$Work = P \times V$$

Cor Pulmonale





Systemic Consequences:

- Breathlessness
- Chronic Fatigue
- Swollen Legs (Edema)

Matching Therapy to Pathology

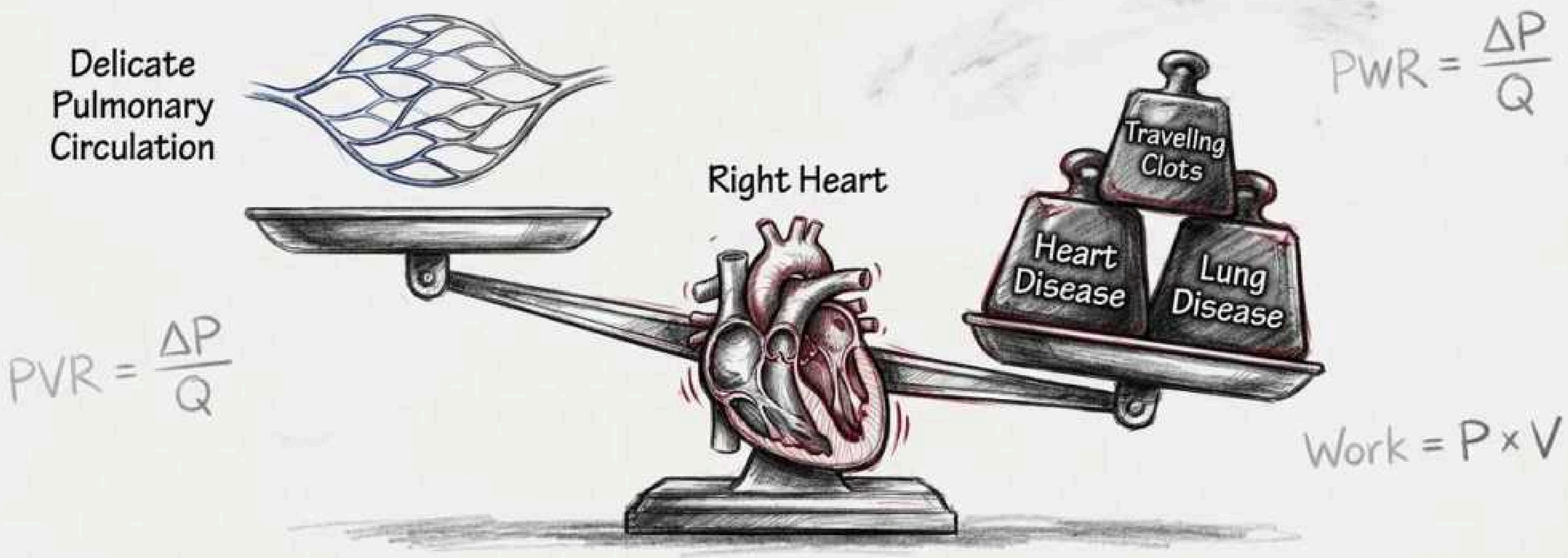
Treatment strictly depends on addressing the underlying cause.

Pathology	Targeted Intervention
Left Heart Disease	Treat underlying heart condition
Chronic Lung Disease	Oxygen Therapy (for low levels)
Chronic Clots	Anticoagulation and sometimes surgery
Pulmonary Arterial Hypertension	Specialised drugs that widen pulmonary arteries Developed since the 1990s — greatly improved the outlook for an originally rapidly fatal condition.

$PVR = \frac{\Delta P}{Q}$ $PVR = \frac{\Delta P}{Q}$ $Work = P \times V$ $R = \frac{8\eta L}{\pi r^4}$ $Work = P \times V$

The Vulnerability of a Low-Pressure System

The pulmonary circulation is a delicate balance. Both sudden blocks and slow pressure rises ultimately exact their toll on the right heart.



Next Lecture Preview: Bringing the systems together in respiratory failure, sleep-related breathing disorders, and lung cancer.