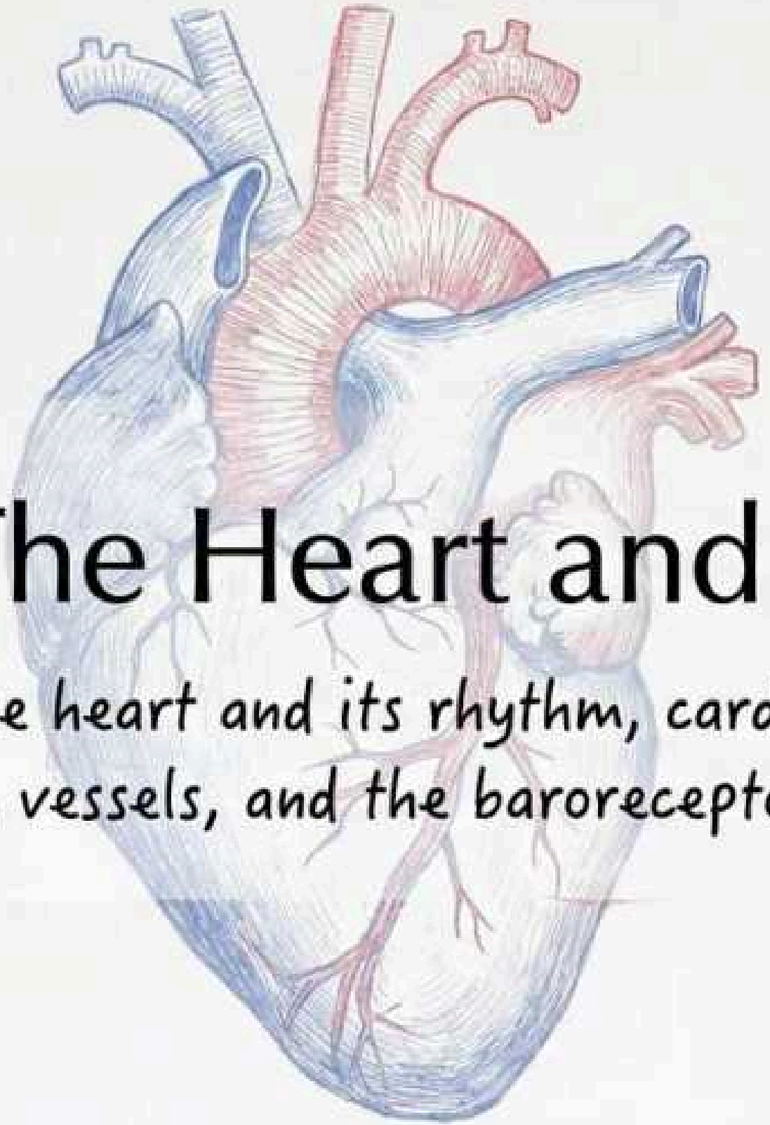
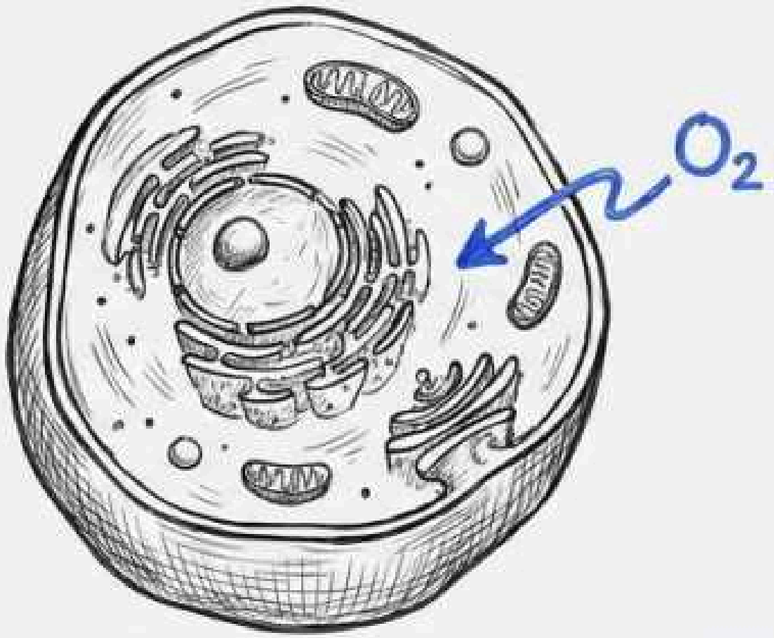
¶ 3.1



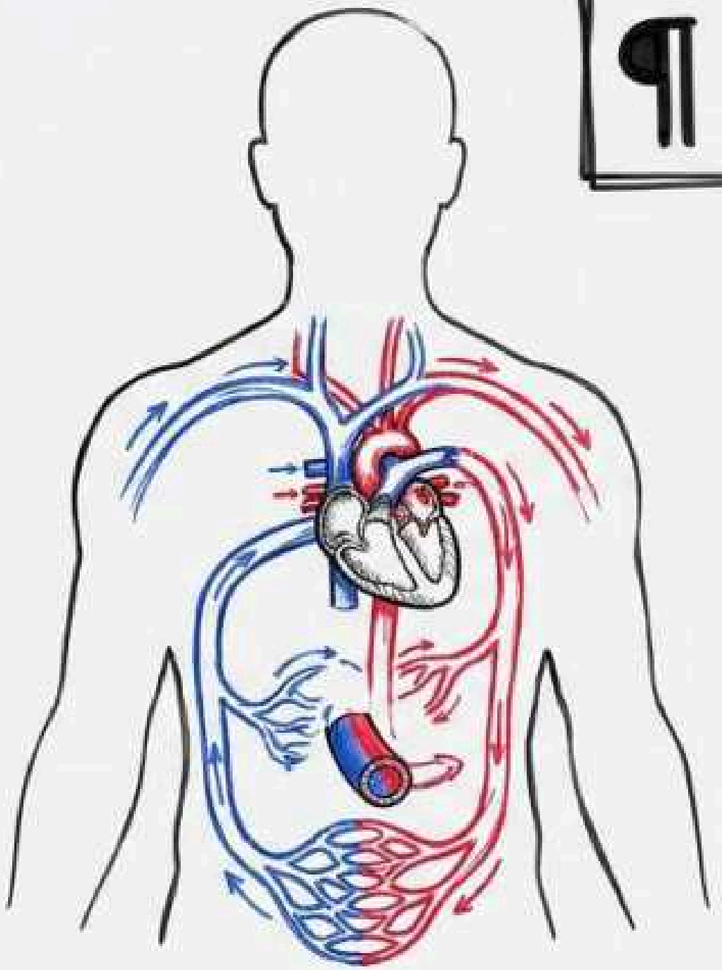
Lecture 3: The Heart and Circulation

At a glance — The heart and its rhythm, cardiac output, blood pressure, vessels, and the baroreceptor reflex.

¶ 3.2



Cells cannot wait for oxygen to drift in from far away.



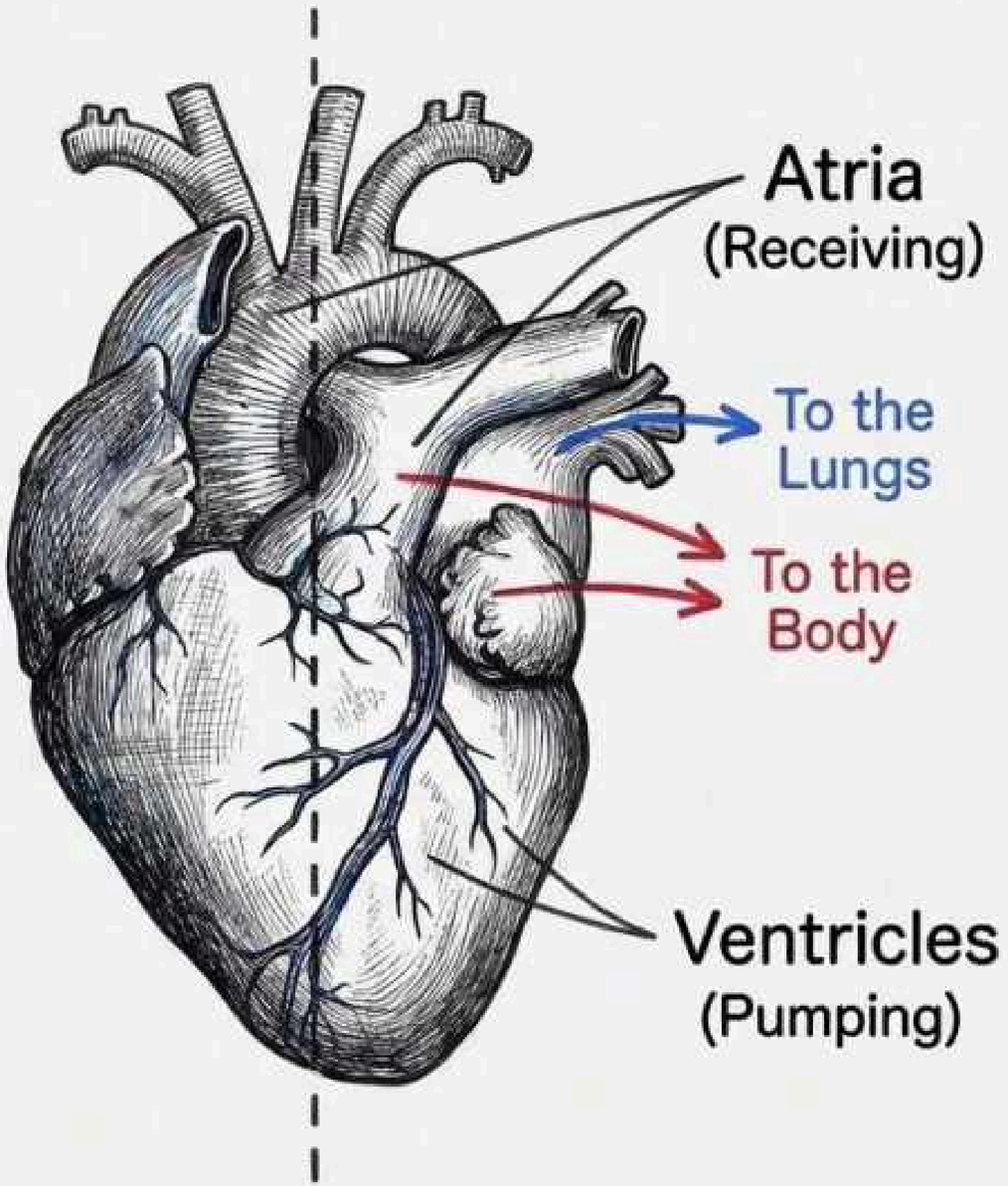
The Solution: A Pump (Heart) & Pipes (Vessel Network)

Lecture scope: Cardiac cycle, blood pressure, output calculation, and moment-to-moment regulation.

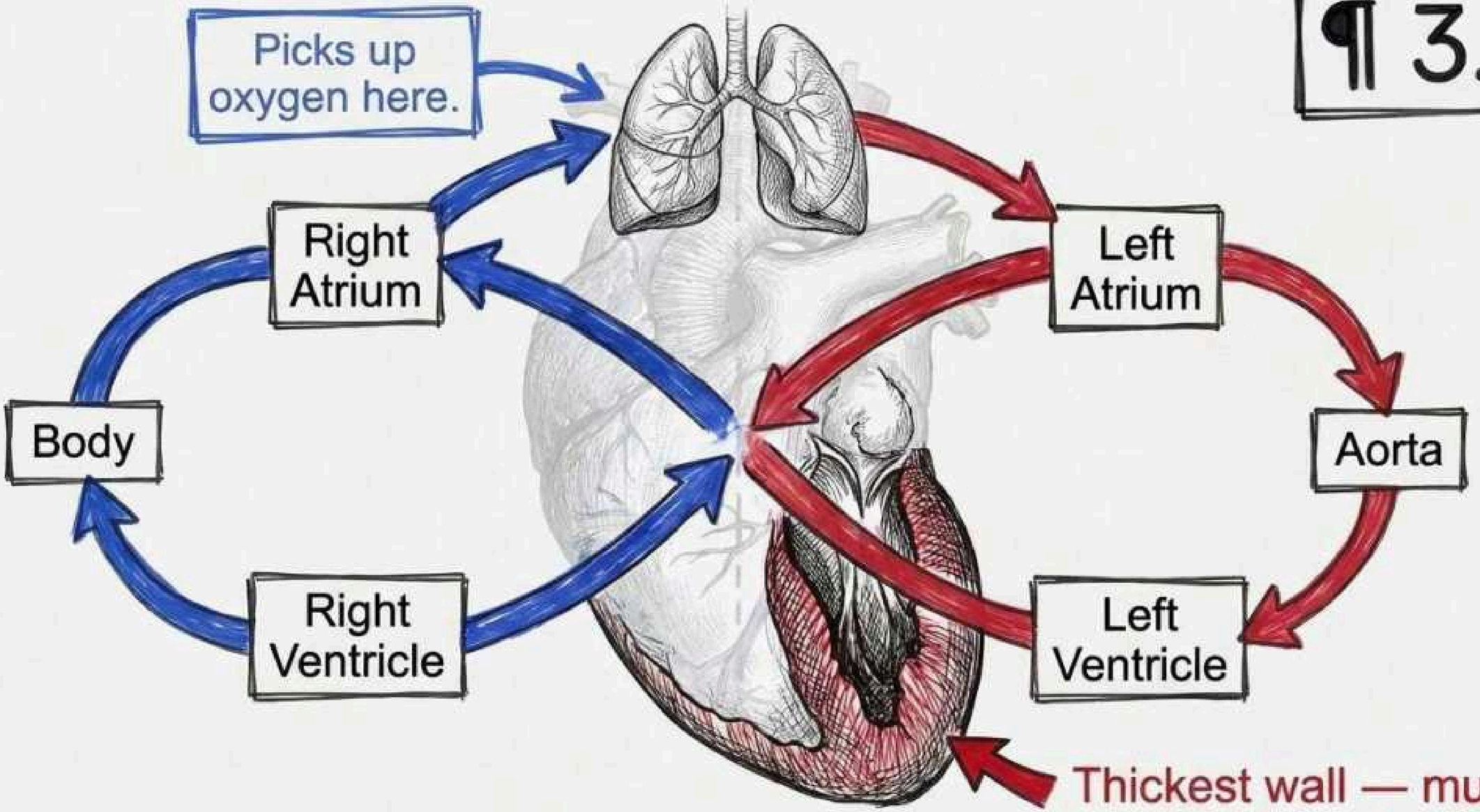
¶ 3.3

A muscular pump
about the size of a fist.



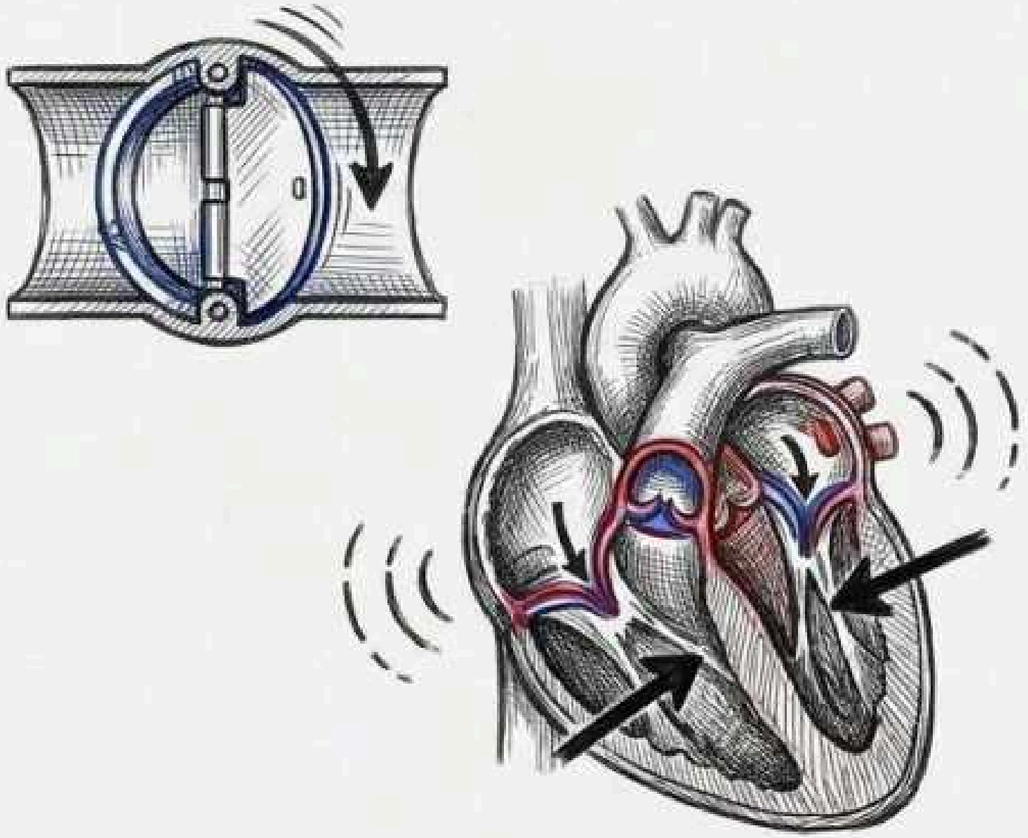


¶ 3.4

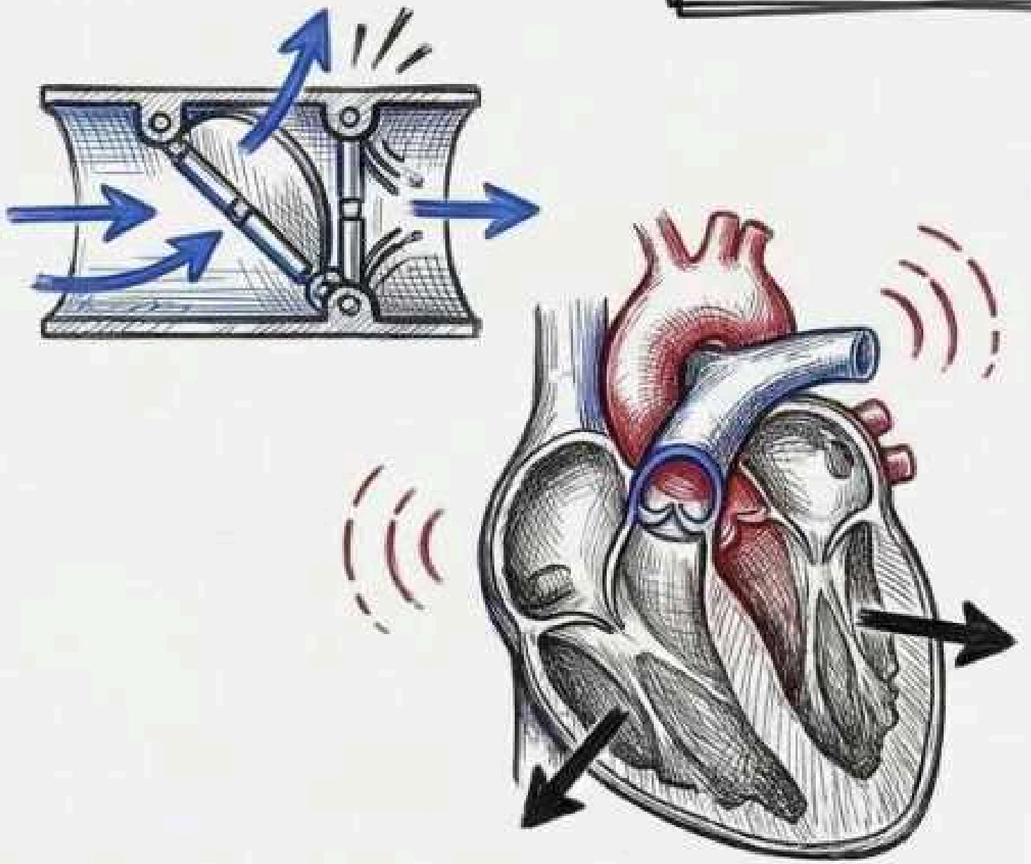

Picks up oxygen here.
Right Atrium
Body
Right Ventricle
Left Atrium
Aorta
Left Ventricle
Thickest wall — must drive blood the farthest.

Four valves ensure one-way flow.

¶ 3.5

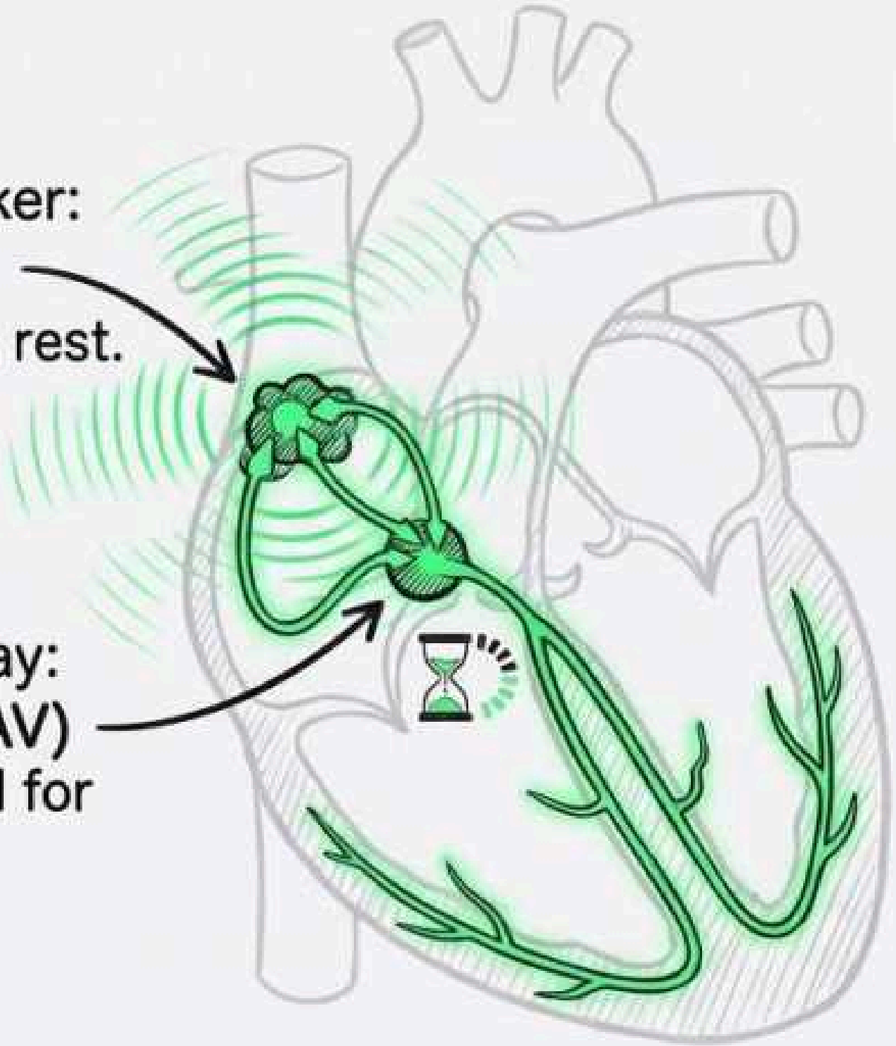


LUB — Inlet valves shut as ventricles squeeze.



DUB — Outlet valves shut as ventricles relax.

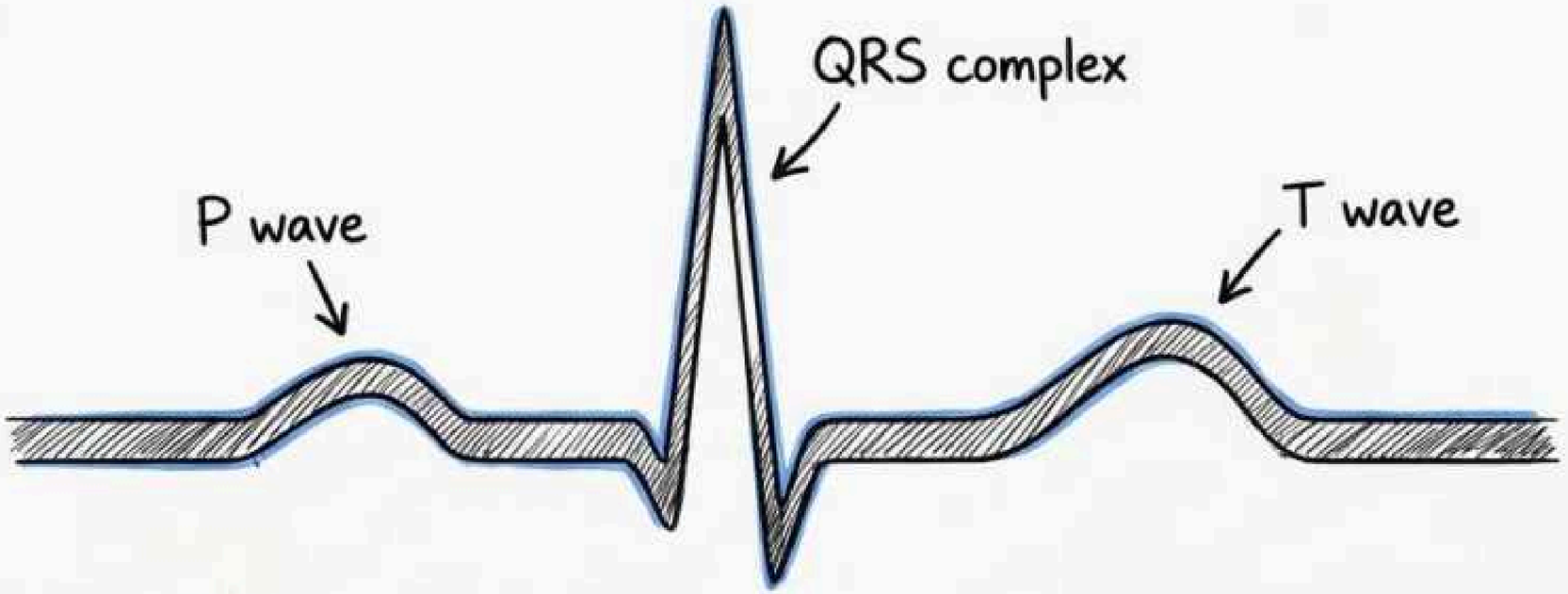
The Natural Pacemaker:
Sinoatrial (SA) Node
fires ~70 times/min at rest.

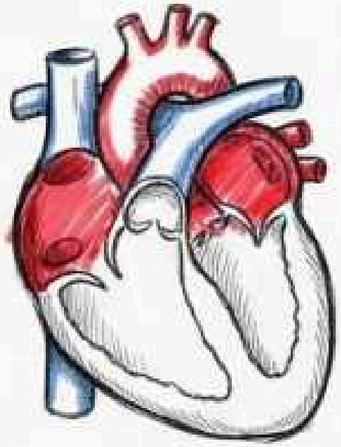


The Signal Relay:
Atrioventricular (AV)
Node pauses the signal for
~0.1 seconds.

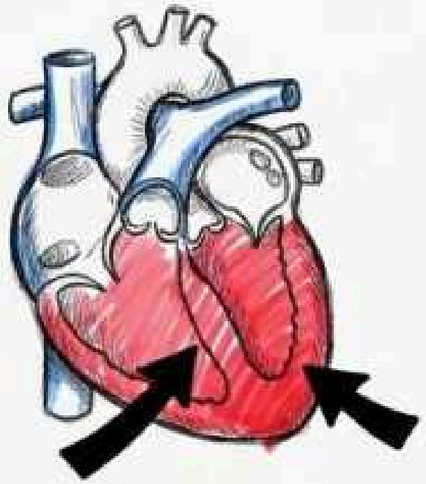
Note: Beats without any outside command.

¶ 3.7

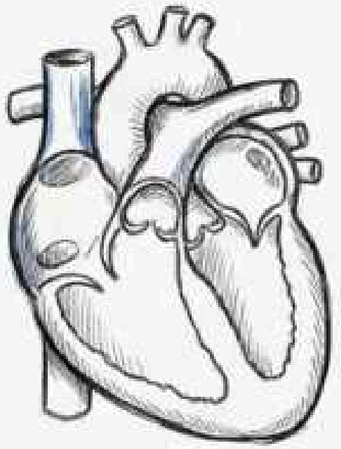




Atria finish emptying (during 0.1s pause)



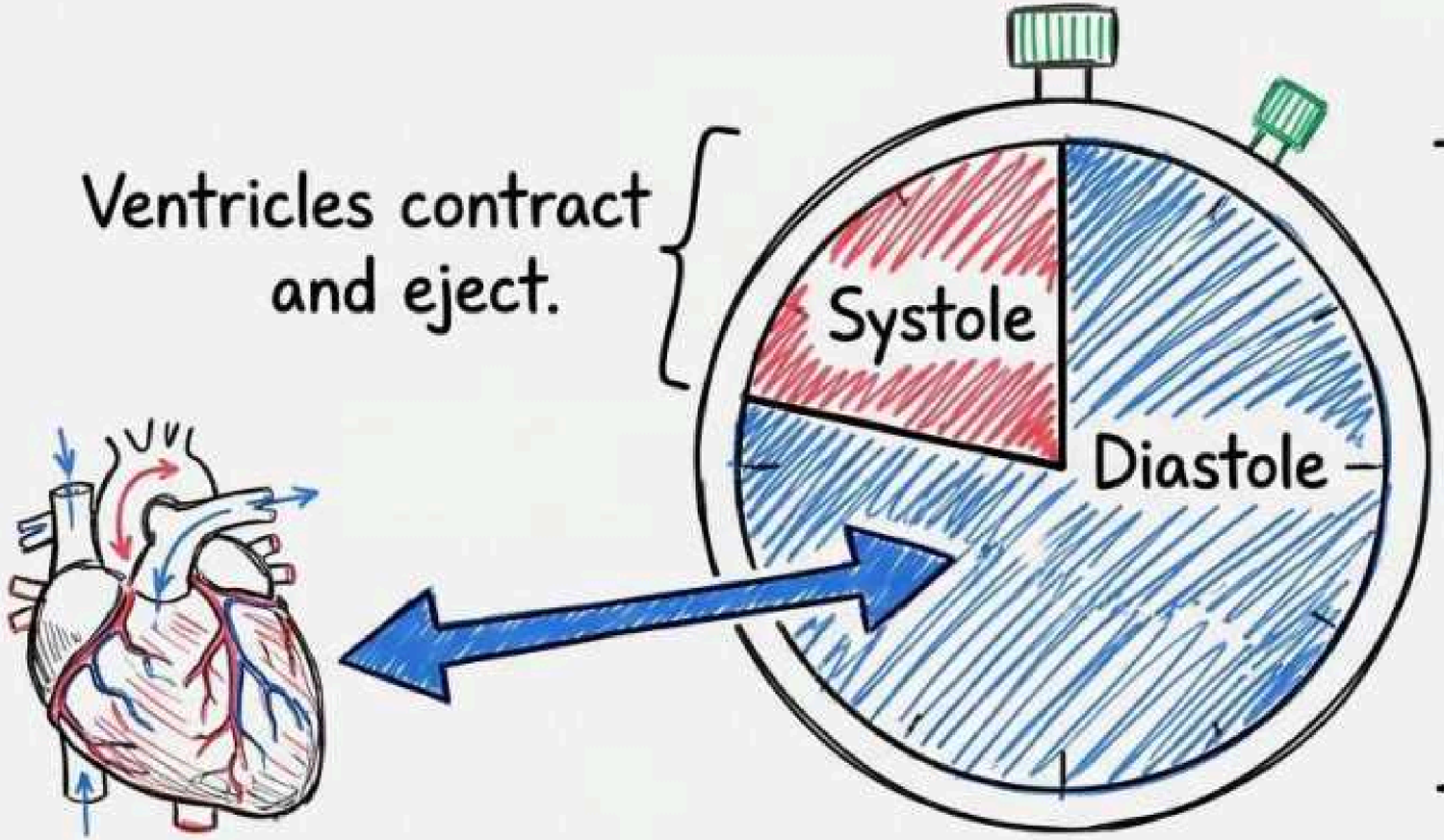
Special fibers carry signal; Ventricles contract from the bottom up.



Ventricles relax/reset.

1 Cycle = 0.86 seconds (at 70 bpm).

¶ 3.8



Key Insight: The heart's own blood supply arrives during Diastole.
Fast heart rates reduce refill time, tiring the heart.

¶ 3.9

Cardiac Output
(Volume pumped per minute)

Heart Rate
(Beats per min)

CO = HR × SV

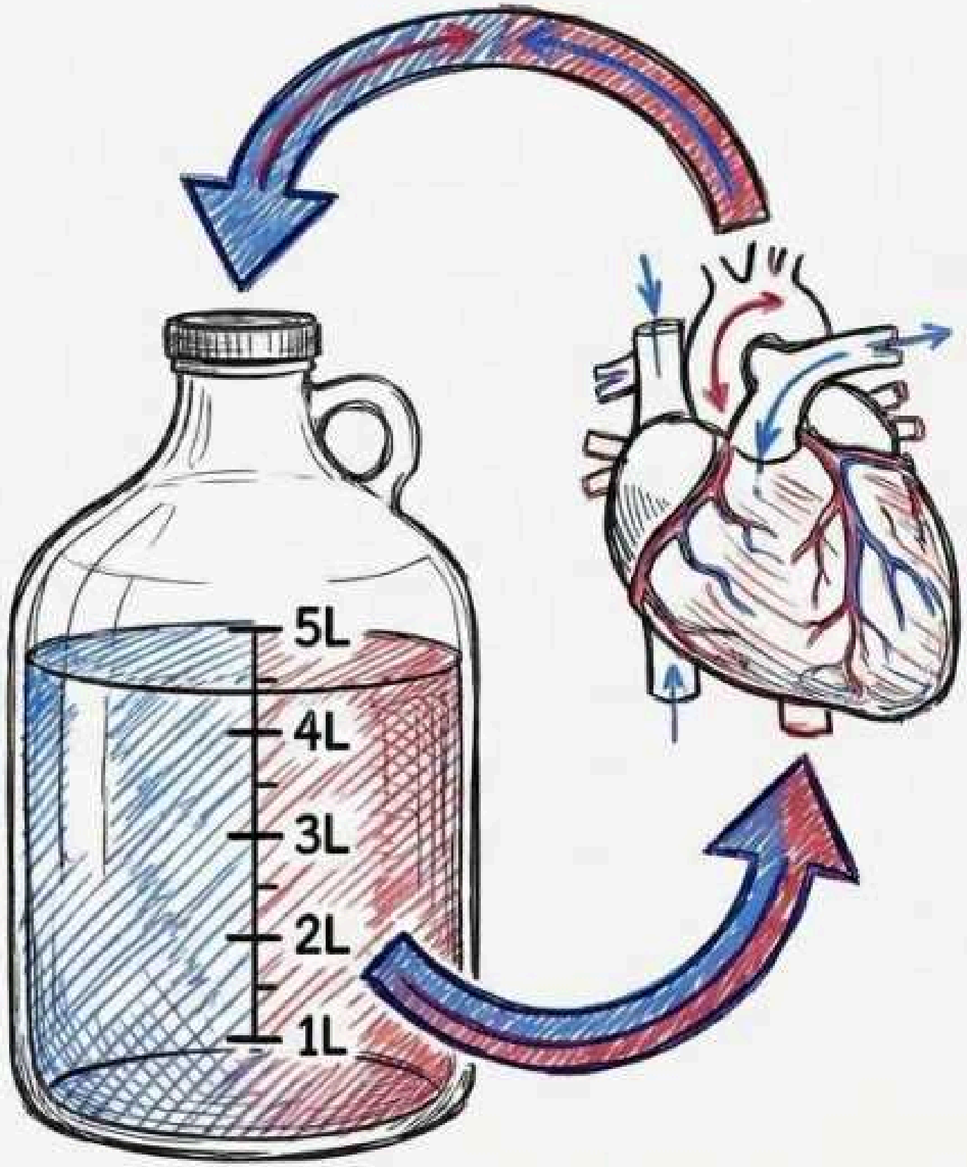
Stroke Volume
(Amount ejected per beat)

70 bpm x 70 mL/beat = 4,900 mL/min

Close to 5 Liters per minute at rest.

Total blood volume = ~5 Liters.

¶ 3.10



1 Minute: Entire supply cycles the heart once.

1 Day: 100,000 beats moving >7,000 Liters.

80-Year Lifetime: ~3 Billion beats.

¶ 3.11

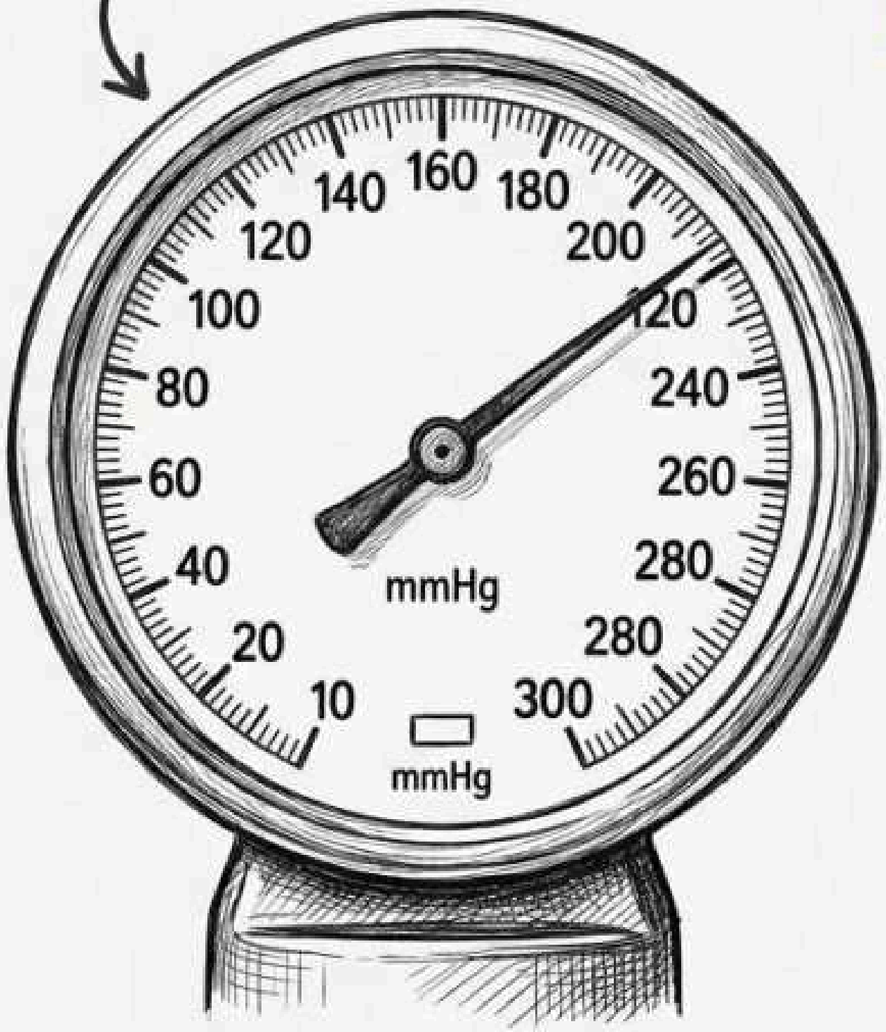
Metric	At Rest	Hard Exercise
Heart Rate	70 bpm	180 bpm
Stroke Volume	70 mL	120 mL
Cardiac Output	~5 Liters/min	~22 Liters/min (21,600 mL)

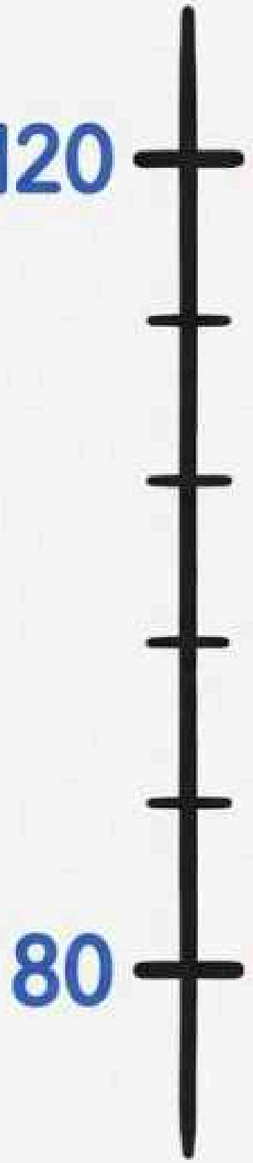


Trainer's Note: Training mainly increases Stroke Volume. Each beat moves more blood, resulting in a slowr resting pulse for athletes.

¶ 3.12

Measured in millimeters of mercury (mmHg).



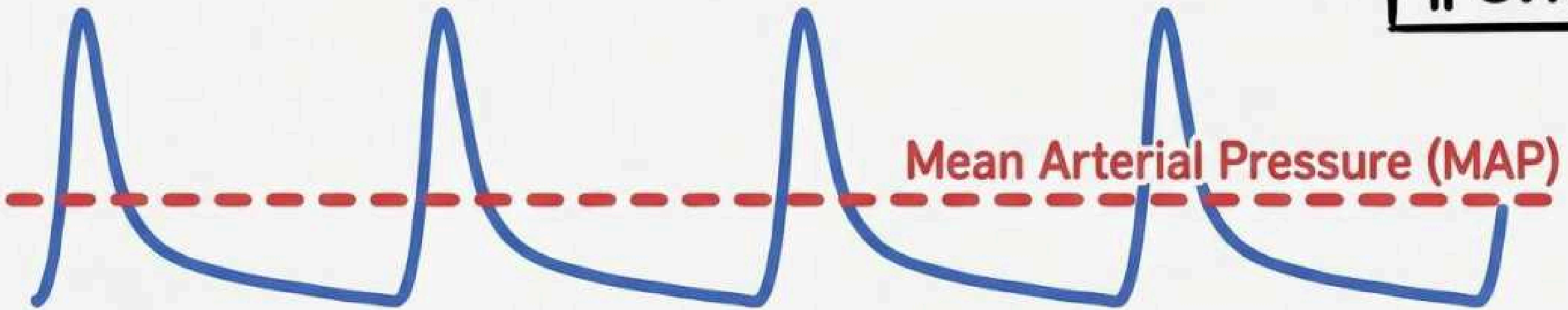


Systolic (120): Peak force on vessel walls during contraction.

Pulse Pressure (40): The difference between systolic and diastolic.

Diastolic (80): Lowest point during relaxation.

¶ 3.13



MAP = Diastolic + 1/3 (Pulse Pressure)

80 + 1/3(40) = 93

Key Insight: Why 1/3? Diastole lasts longer than systole, so the average pressure sits closer to the bottom number.

¶ 3.14

Physics: Pressure = Flow x Resistance

Biology: MAP = Cardiac Output (CO) x Total Peripheral Resistance (TPR)

If heart pumps more (↑CO), pressure rises.

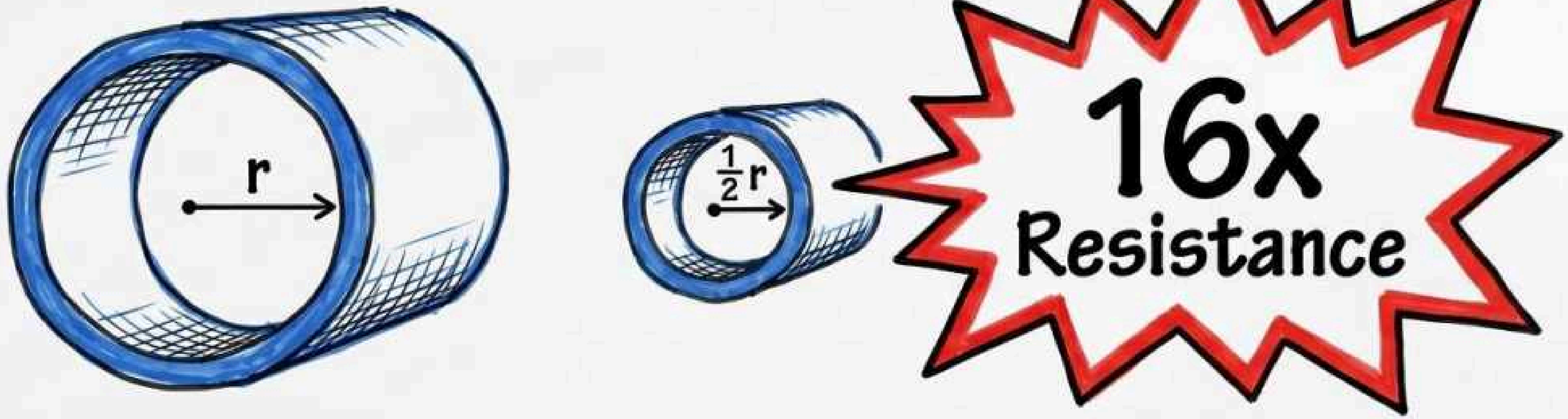
If vessels narrow (↑TPR), pressure rises.

Note: Most resistance lies in arterioles (small arteries) which tighten or relax.

¶ 3.15

$$R \propto \frac{1}{r^4}$$

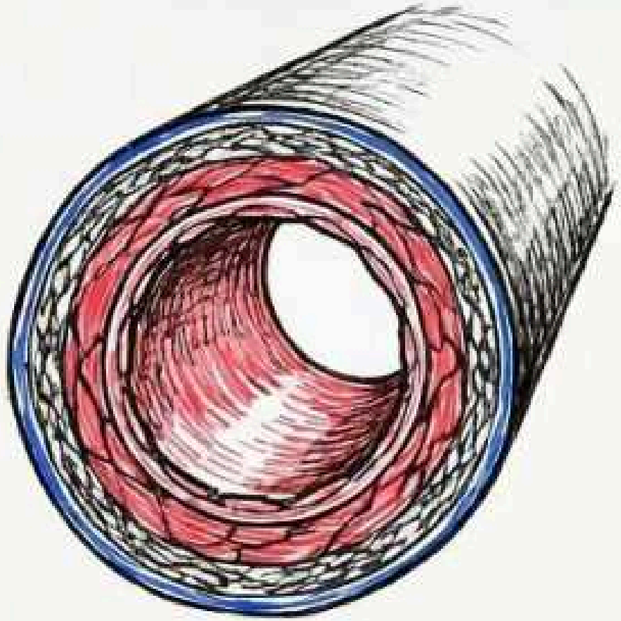
Resistance varies as the inverse of the radius to the fourth power.



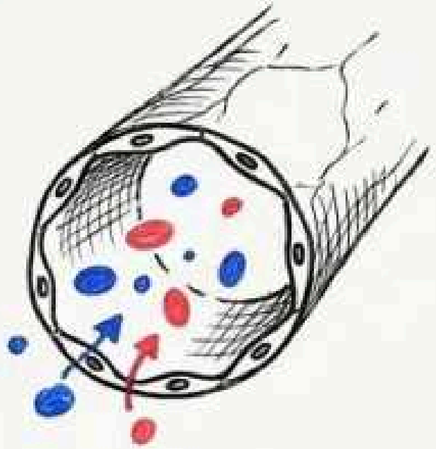
Halve the radius = Resistance rises 16-fold.

Clinical Application: A small narrowing by fatty deposits or tightening muscle has a massive effect. Drugs that relax arterioles effectively drop blood pressure.

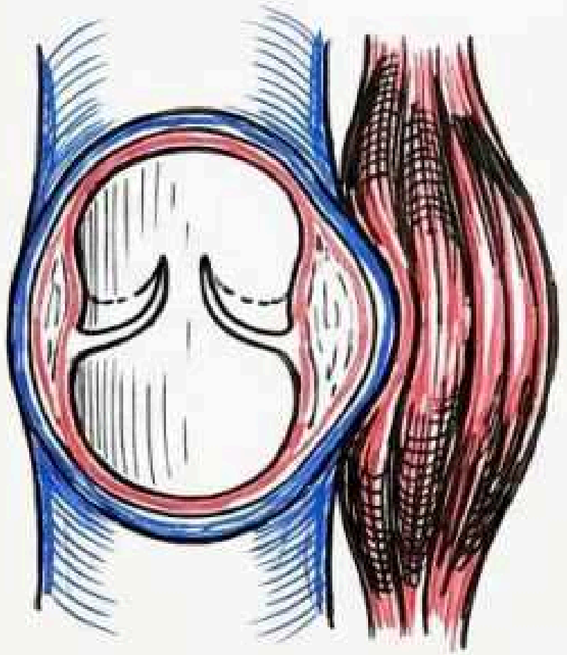
¶ 3.16



Arteries: High pressure, thick/elastic, carry blood away. (Arterioles regulate flow).



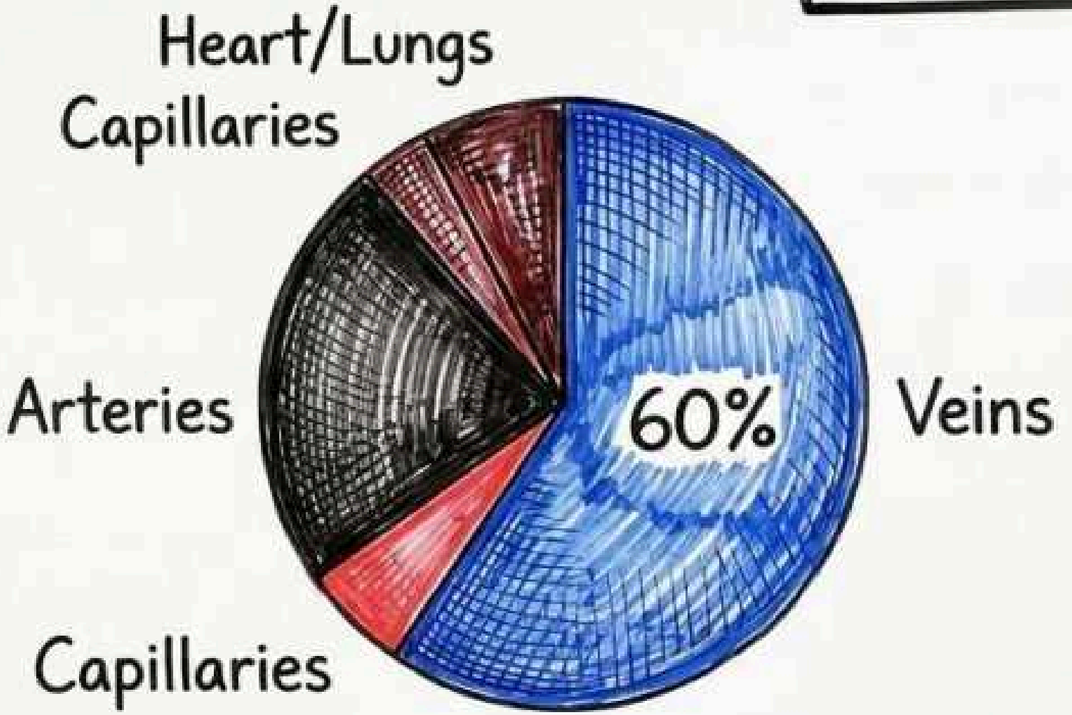
Capillaries: Walls one cell thick. For exchange of oxygen, nutrients, waste.



Veins & Venules: Low pressure return. Rely on valves and skeletal muscle squeezing to push blood uphill.

¶ 3.17





Capillaries: Tens of thousands of kilometers if laid end-to-end. No cell is more than a fraction of a millimeter away. Flow is slow here to allow time for exchange.

Veins: Act as a reservoir. At rest, ~60% of blood sits in the veins.

¶ 3.18



Step 1:
Stand up

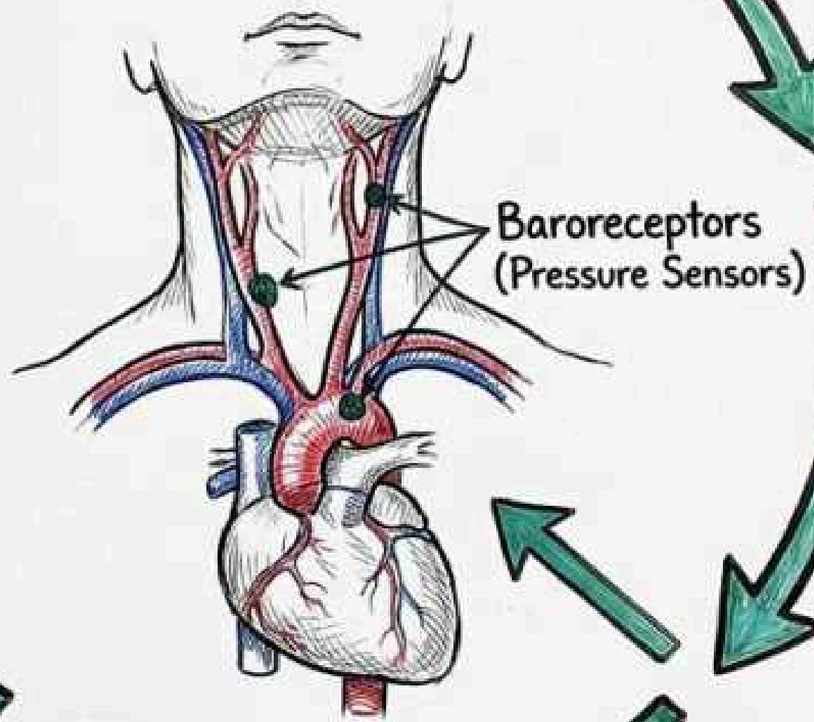
Gravity pulls blood to legs.

Step 2:
Pressure at the head drops.

Step 3:
Baroreceptors report drop to Brain.

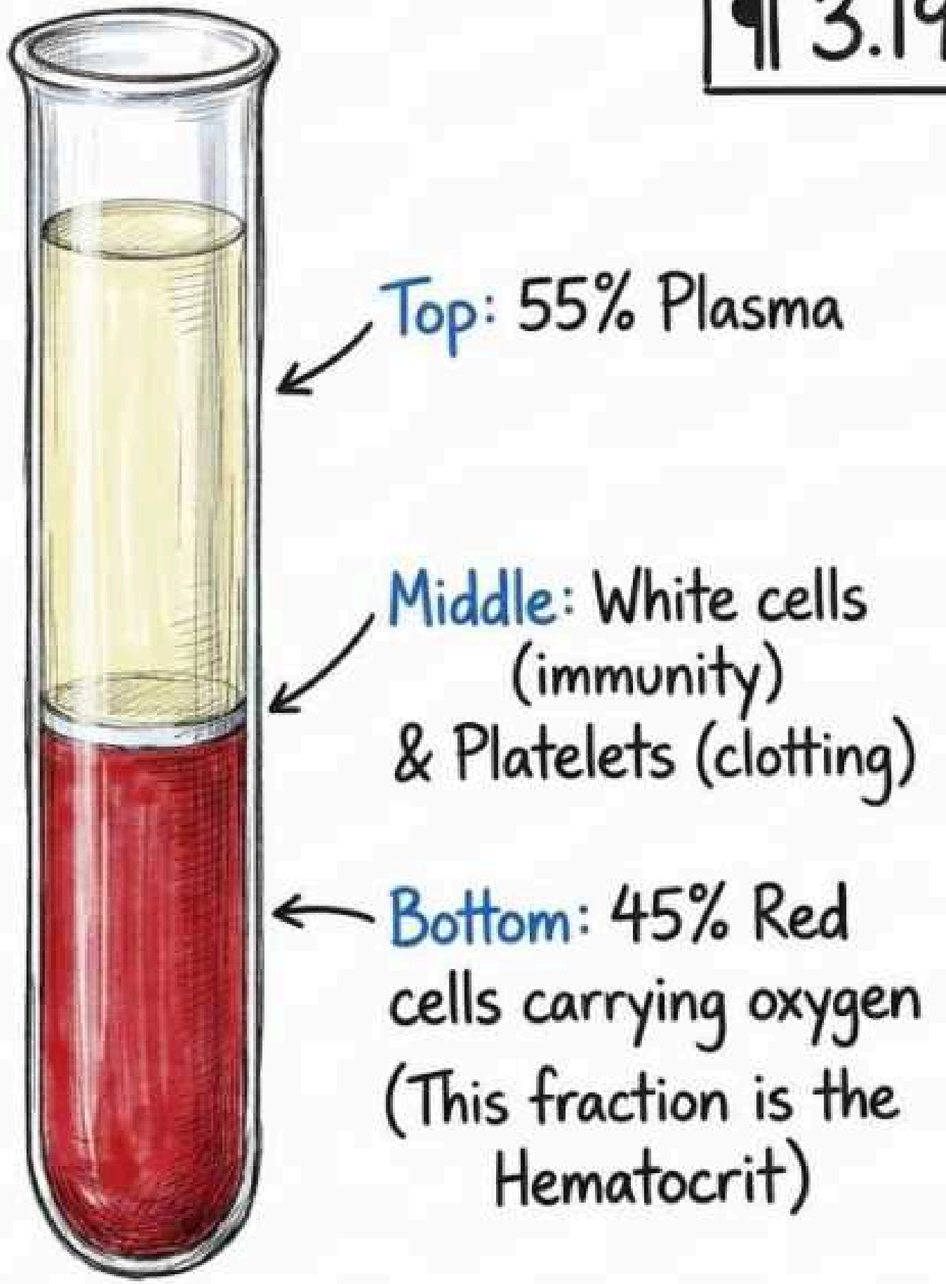
Step 4:
Brain speeds heart & narrows vessels.

Step 5:
Pressure restored (within seconds).



¶ 3.19

- Slow reflex = dizziness on standing. (Causes: dehydration, medicine, age).



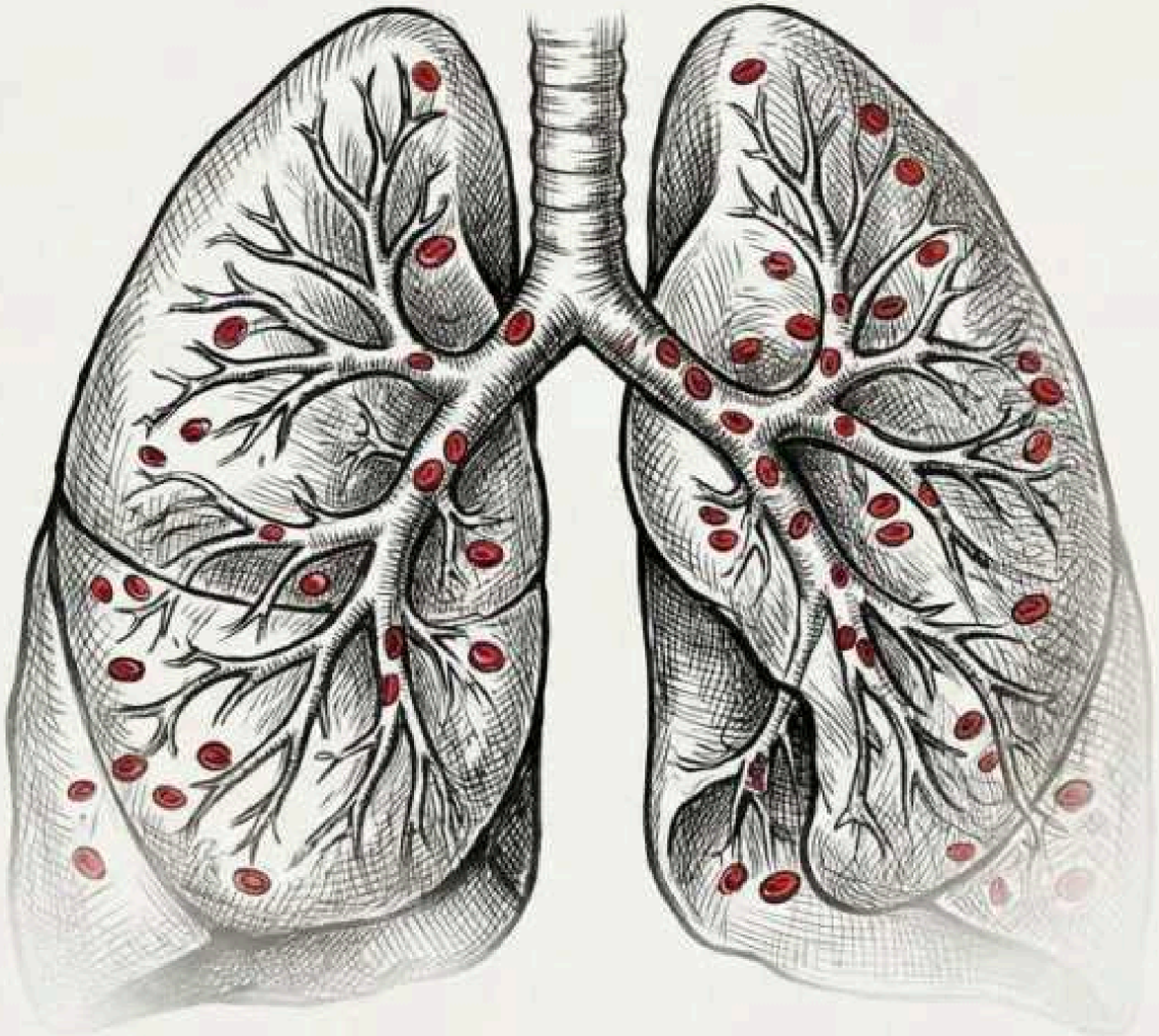
POP QUIZ

¶ 3.20

Question 1: A person has a Heart Rate of 80 bpm and a Stroke Volume of 60 mL. What is their Cardiac Output?

Question 2: If the arterioles all relax, and cardiac output stays the same, what happens to blood pressure? And what will the baroreceptors do in response?

¶ 3.21



Next Time: Lecture 4 — Breathing and Gas Exchange.

Following the oxygen that this blood is hurrying to collect.