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Systemic Stress Response

M1 – Cardiovascular/Respiratory Sequence

Louis D’Alecy, Ph.D.

Fall 2008

Wednesday 11/12/08, 9:00
Systemic Stress Response

(After Baroreceptor Reflex)

34 slides, 50 minutes

1. Reflex response to hemorrhagic stress
2. **What happens next?**
3. Starling forces and fluid shifts
4. Lymph flow
5. Vasoconstriction & absorption
6. VR and CO in hemorrhage

Arterial Baroreceptor Reflex(s)

-minimize changes in arterial blood pressure

- tend to restore MAP to initial value

- moves pressure opposite disturbance

- utilizes (controls) HR, SV, TPR, “other” changes

- can be over ridden by other reflexes and controls

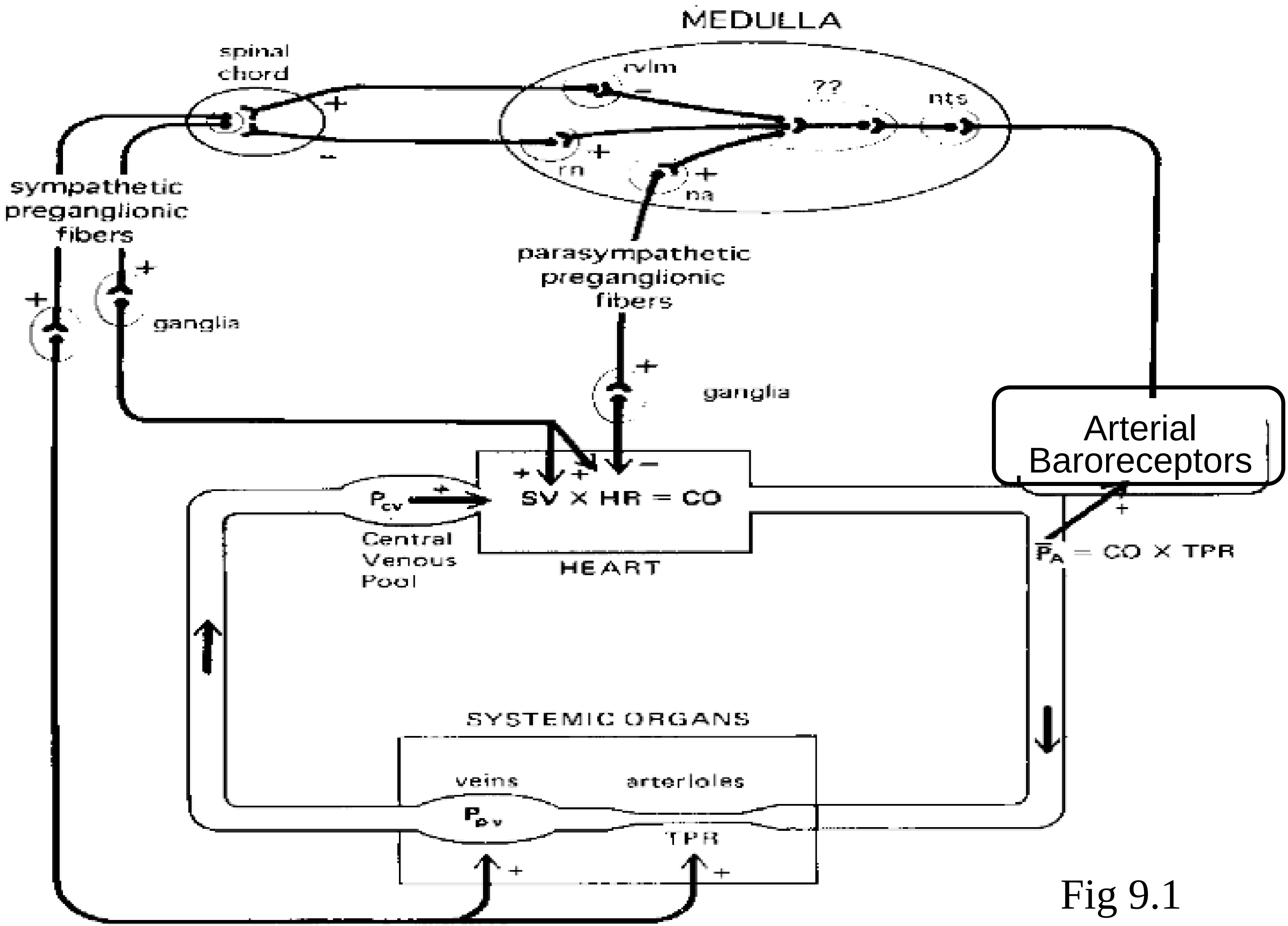


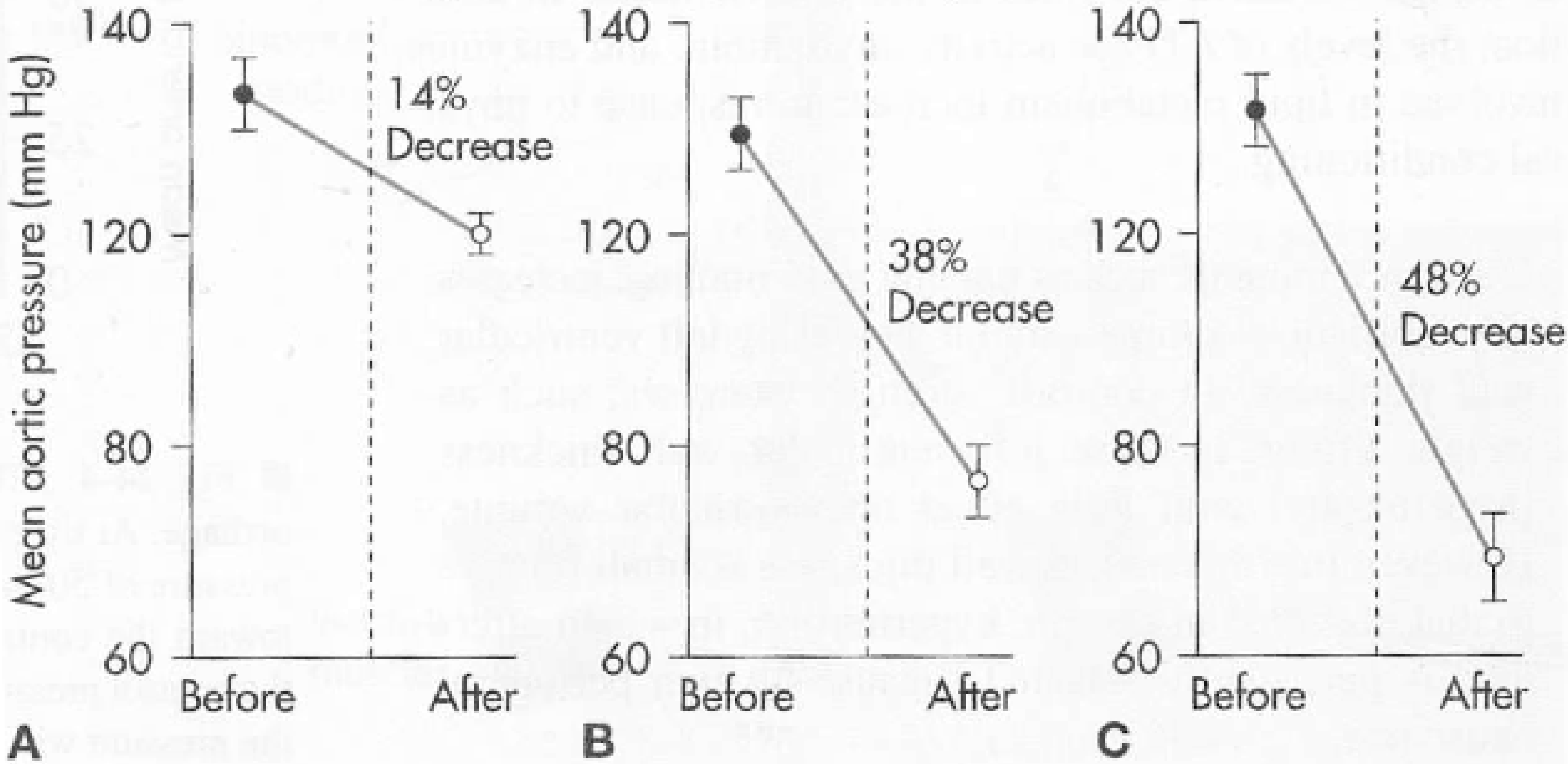
Fig 9.1

 Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.

No aortic baroreceptors

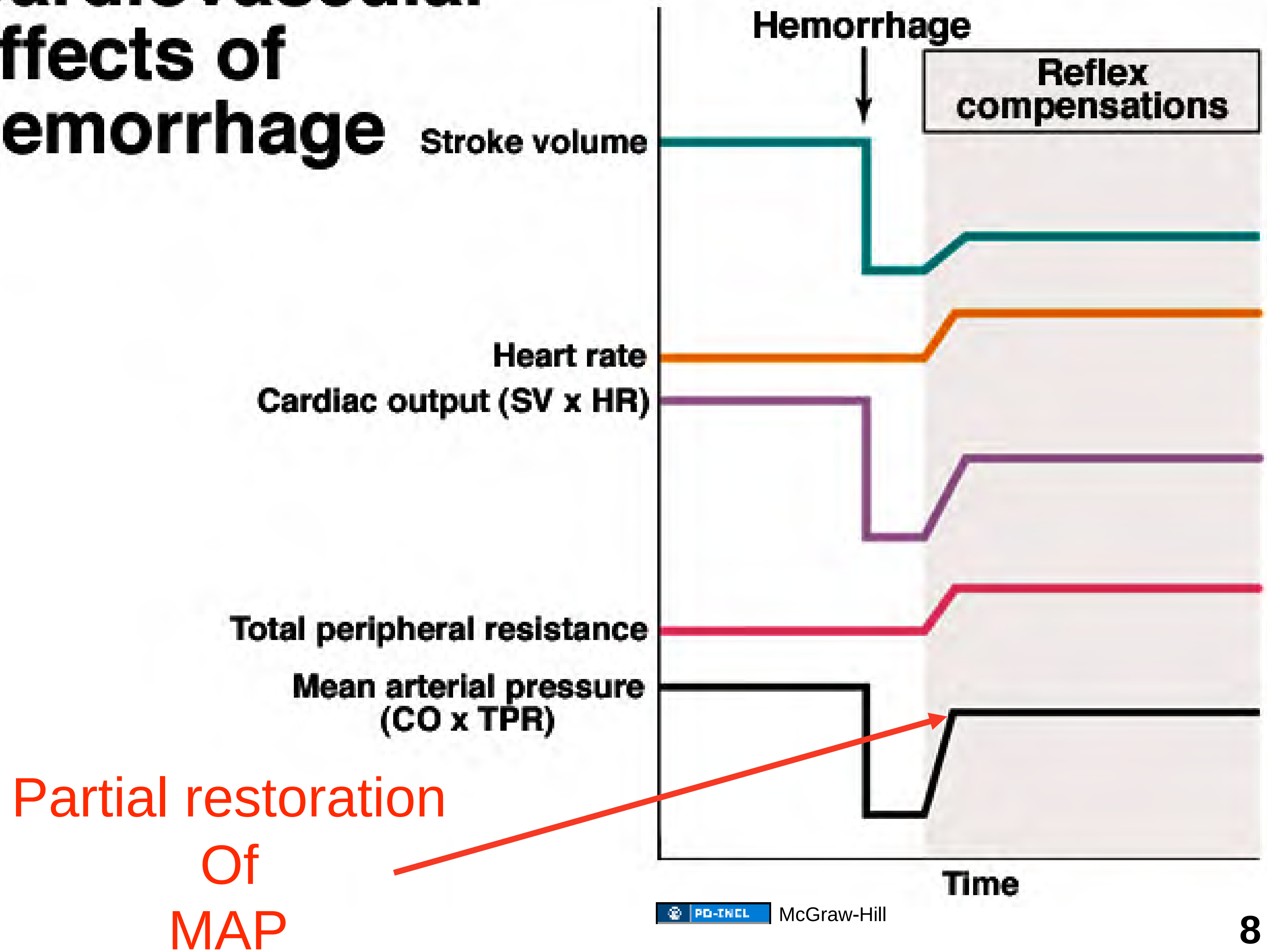
No carotid baroreceptors

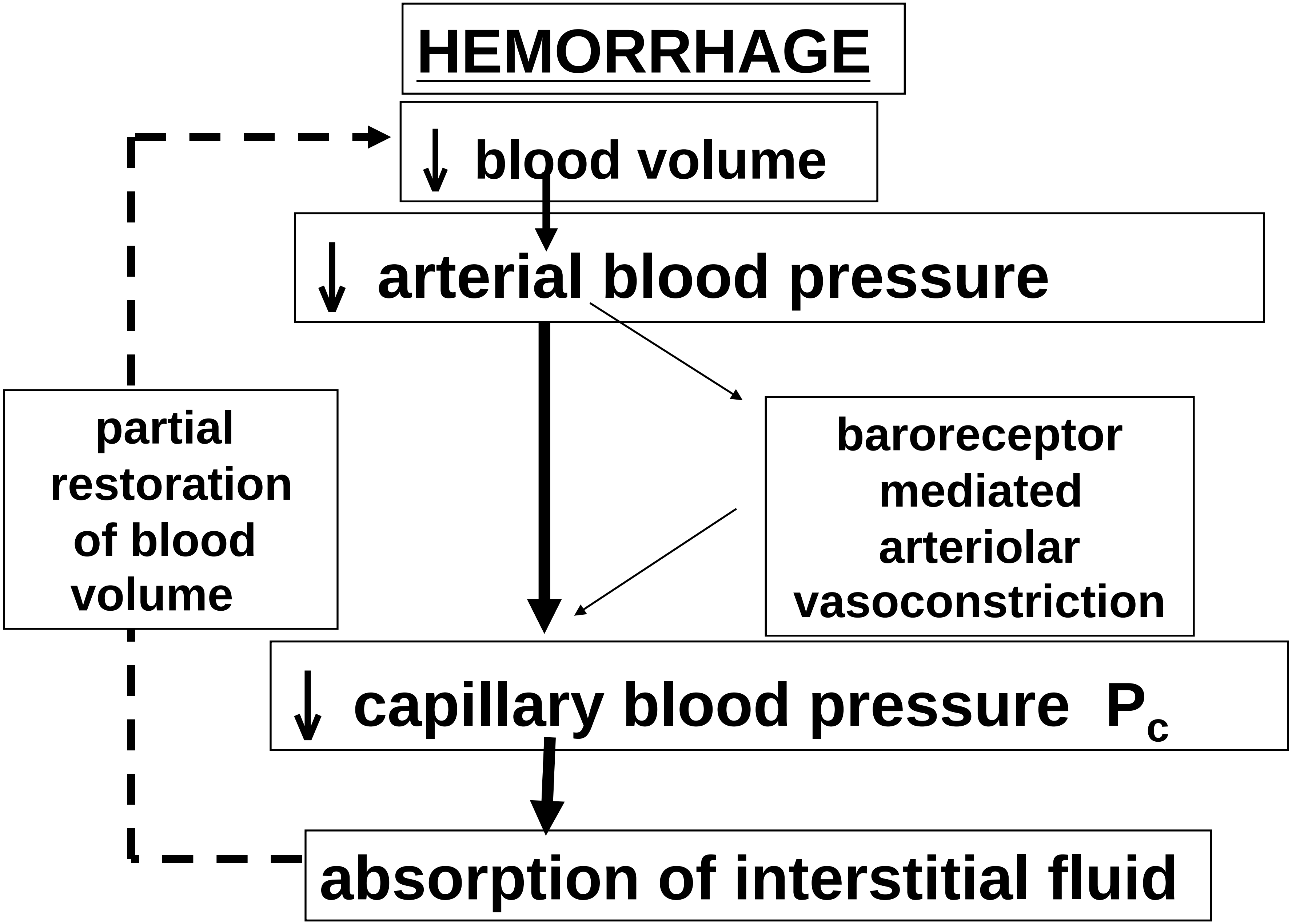
"No" baroreceptors



Intact baroreceptor reflexes minimize the response to hemorrhage involving 20% loss of blood.

Cardiovascular effects of hemorrhage




HEMORRHAGE
↓ blood volume
↓ arterial blood pressure
baroreceptor mediated arteriolar vasoconstriction
partial restoration of blood volume
↓ capillary blood pressure P_c
absorption of interstitial fluid

Fluid Shifts after Hemmorrhage

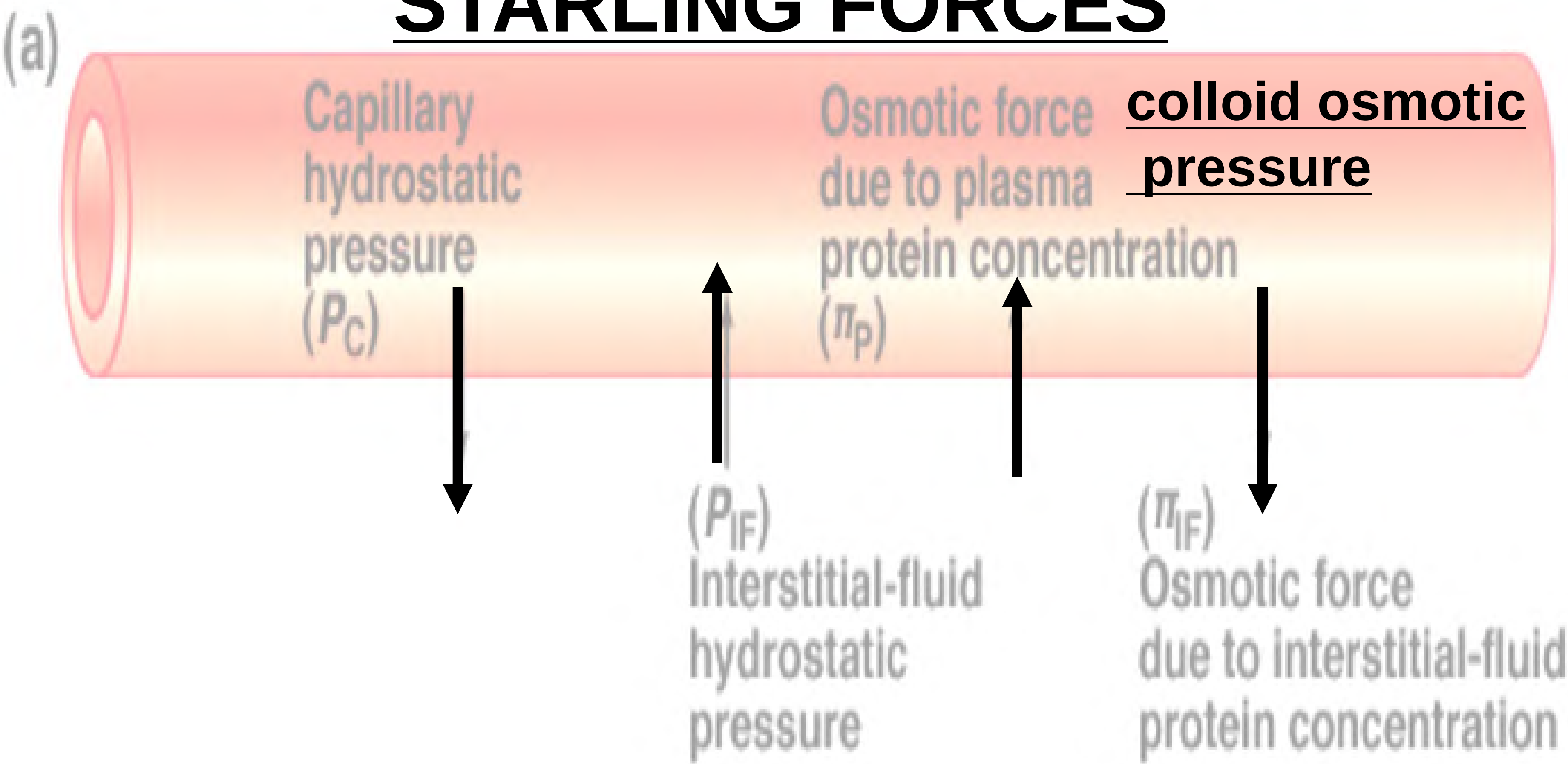
	Normal	Immediately after hemorrhage	18h after hemorrhage
Total blood volume, mL	5000	4000 (↓20%)	4900
Erythrocyte volume, mL	2300	1840 (↓20%)	1840
Plasma volume, mL	2700	2160 (↓20%)	3060
Plasma albumin mass, g	135	108 (↓20%)	125
Hematocrit*	**46**	**46**	**37**

Erythropoiesis

*Hematocrit = % of blood volume occupied by red blood cells

Fluid movement across capillaries

STARLING FORCES



colloid osmotic pressure

Net filtration pressure = $(P_C - P_{IF}) - (\pi_P - \pi_{IF})$

CAUSES OF DECREASED PLAMSA COLLOID OSMOTIC PRESSURE

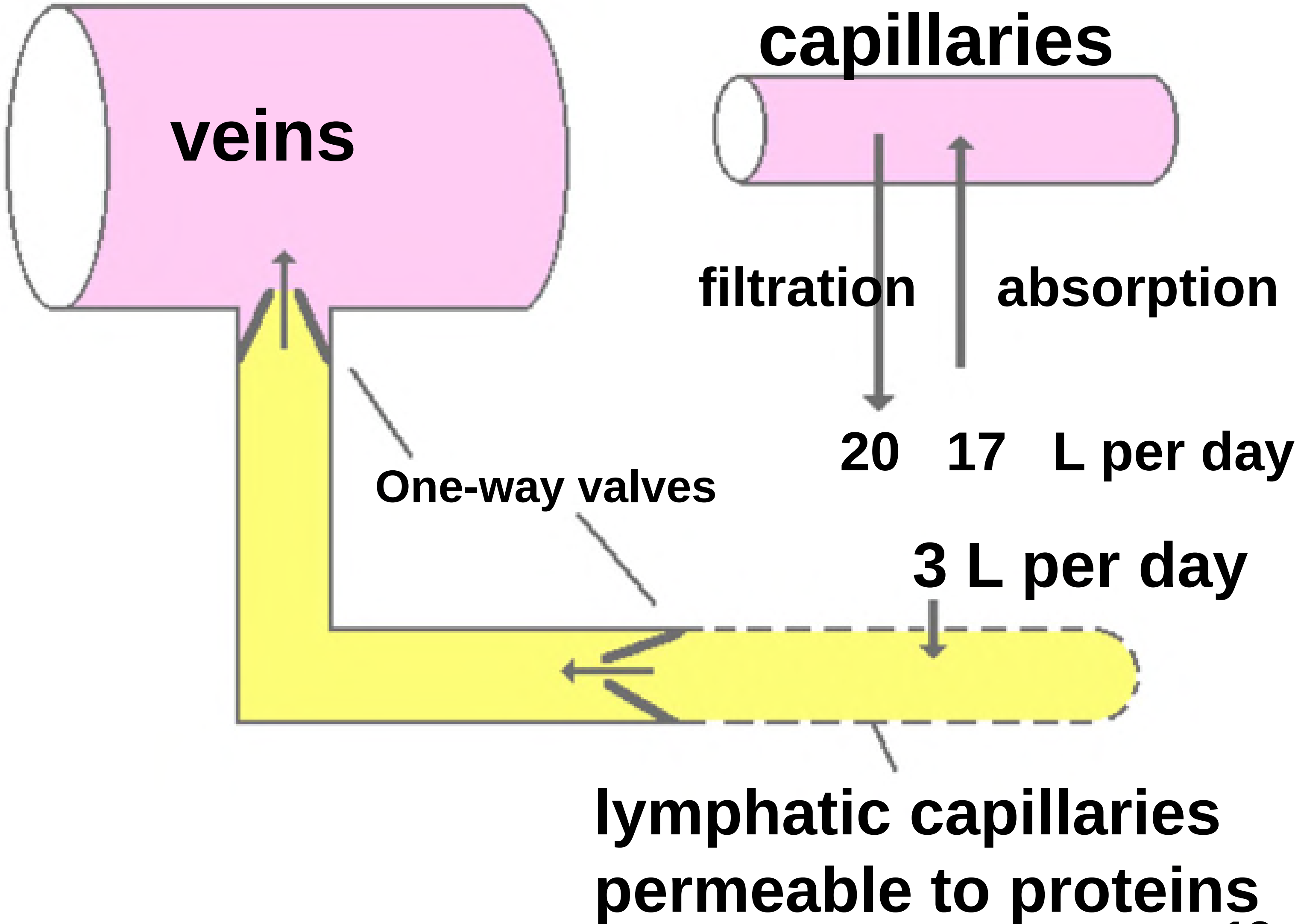
1. ↓ Synthesis of albumen by liver

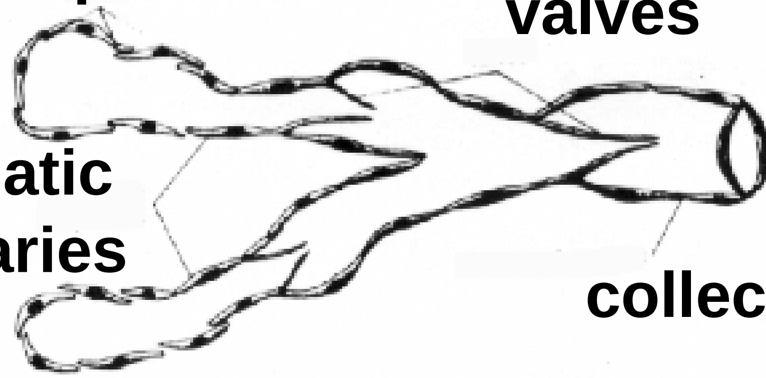
   A. protein malnutrition - decreased amino acid availability
   B. liver disease - decreased formation of plasma proteins

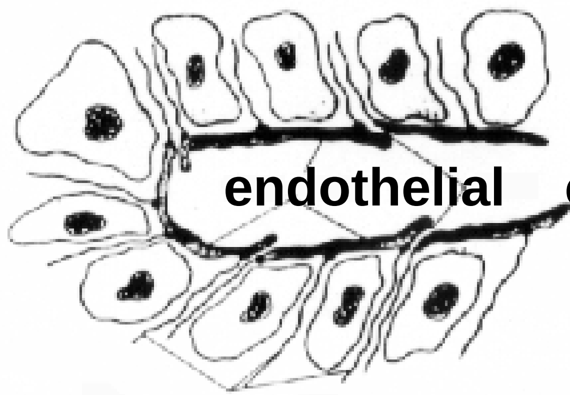
2. ↑ Loss of albumen across capillary walls
   A. burns
   B. kidney disease
   C. GI disease

3. Iatrogenic (excess IV salt solutions, hemodilution)

LYMPHATIC SYSTEM




pores
valves
lymphatic
capillaries
collecting lymphatic


endothelial cells
anchoring filaments

LYMPH FLOW

Bulk fluid flow into lymphatic capillaries

Hydrostatic pressure gradient

1. Increased interstitial fluid volume increases P_{isf}
2. Decreased pressure in lymphatic capillaries

Bulk fluid flow along lymphatic network

1. Rhythmic contractions of lymphatic smooth muscle
   (one way flow due to valves in lymphatics)
2. Tissue compression - skeletal muscle pump

Lymph vessel

Similar to venous blood flow but lower pressure and lower volume.

Contracted muscles =closed valve

Image of skeletal muscle pump removed

Lymph flows toward thoracic duct.

Please see: http://www.vhlab.umn.edu/atlas/phystutorial/graphics/fig3.jpg

LYMPH vs. PLASMA

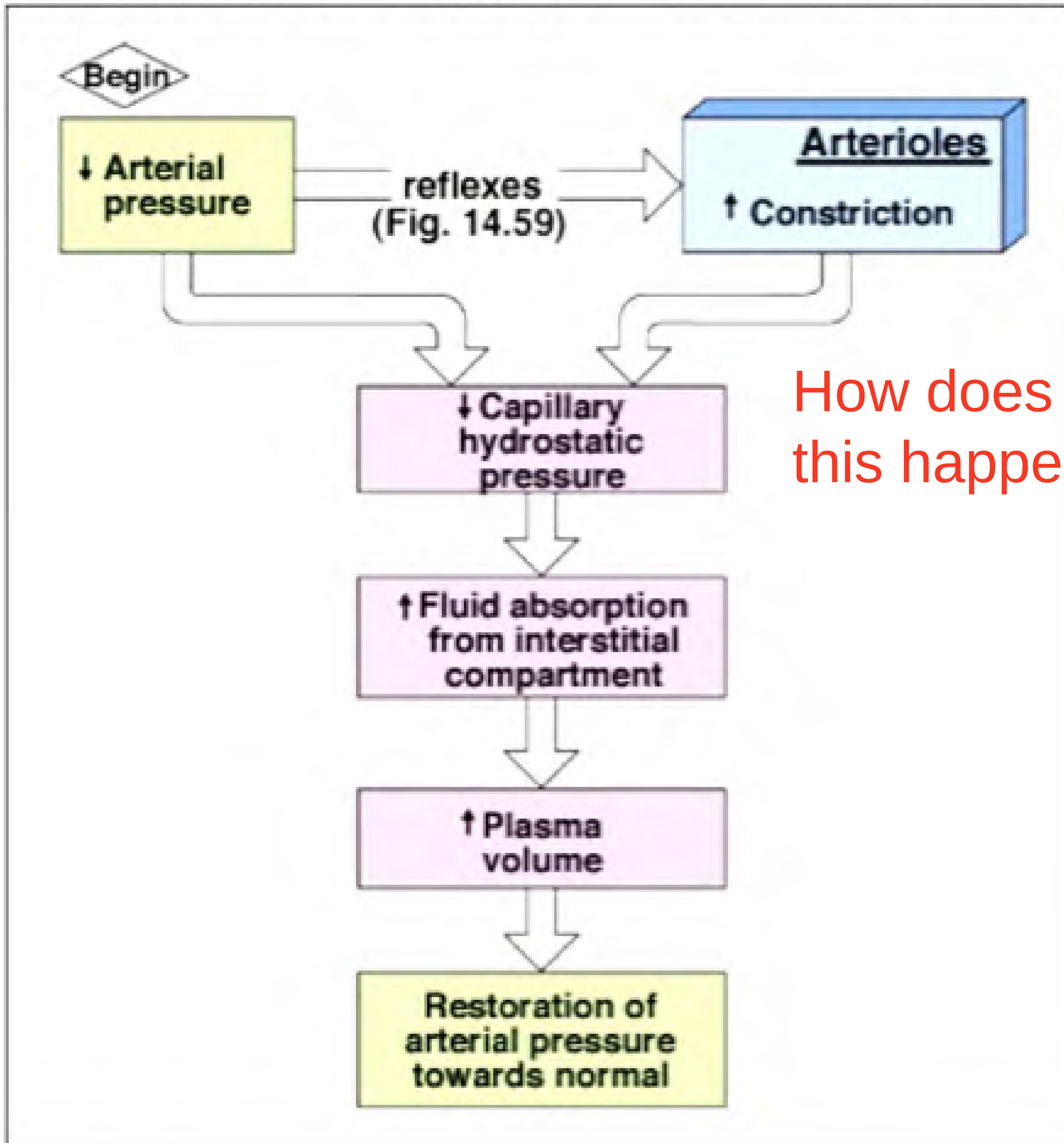
Flow:	Lymph	Plasma
	3 L / day	4320 L / day
	2 mL / min	3000 mL / min

Lymph Volume   4 L (35% of 11 L of interstitial fluid)

Composition
No RBC, some WBC
Small molecular composition equal to venous plasma
Protein composition equal to interstitial fluid

	protein g / L
plasma	73
muscle lymph	20
intestinal lymph	40
liver lymph	50

Movement of interstitial fluid



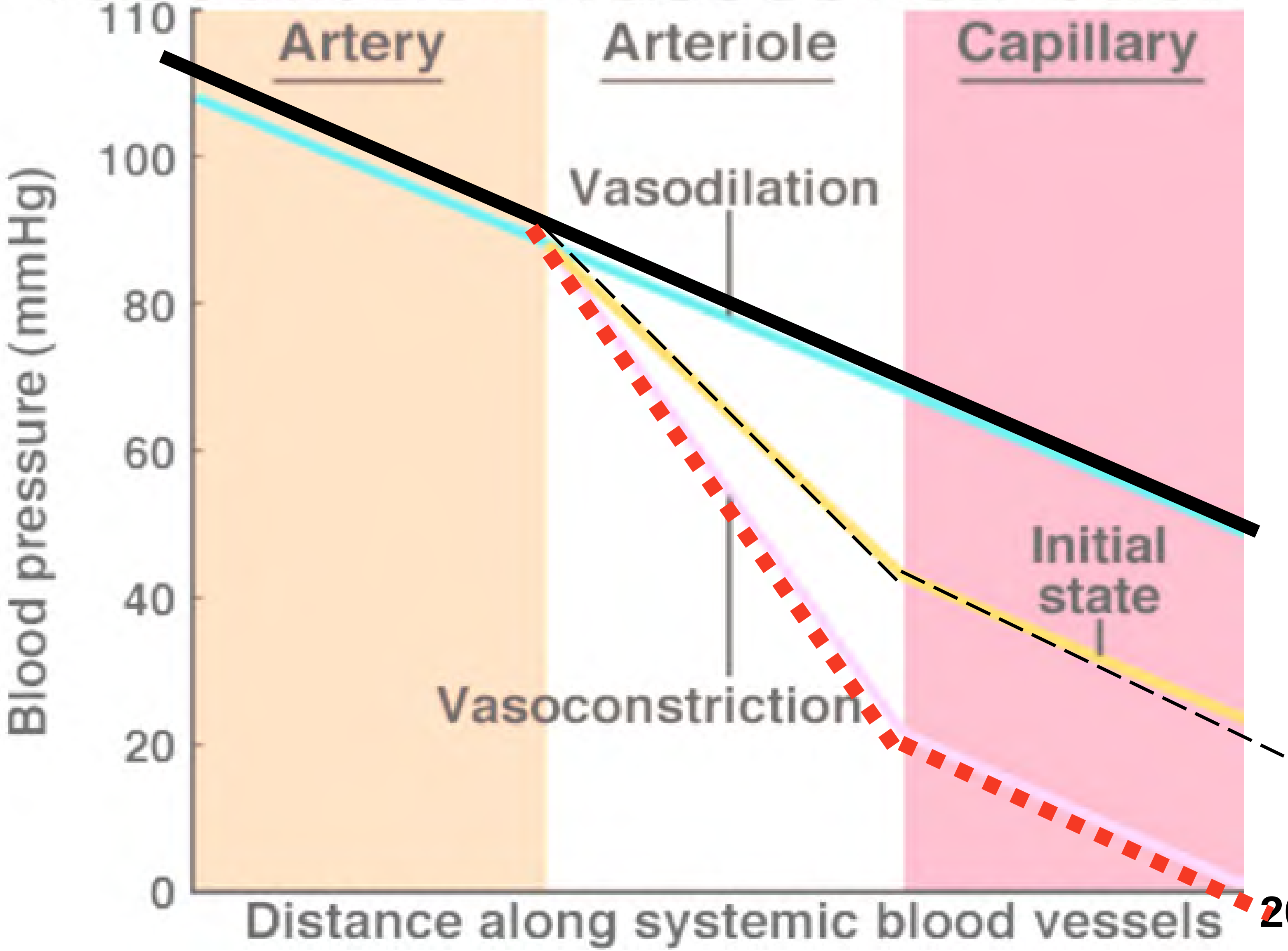
How does this happen?

Back Into the Plasma Compartment

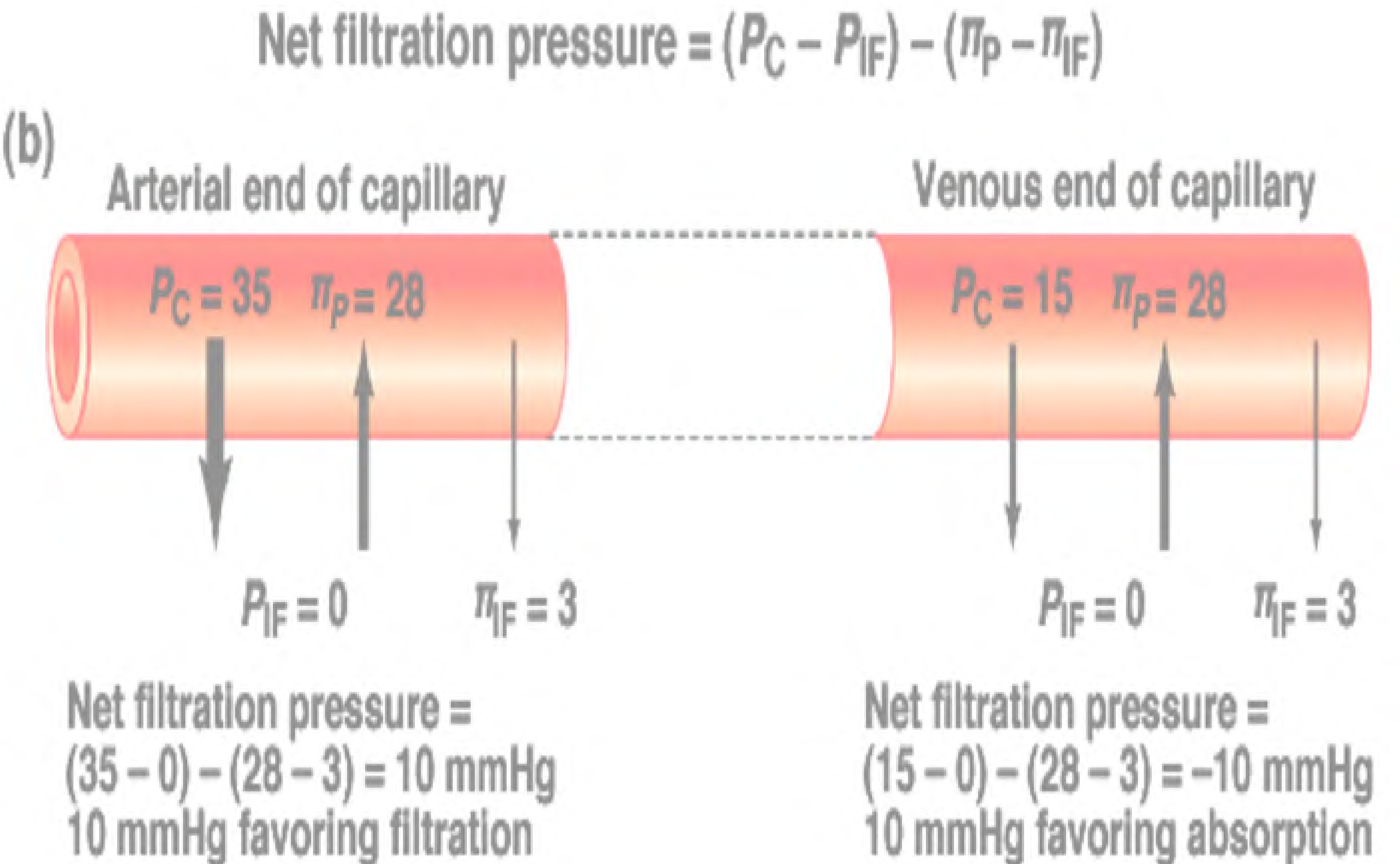
What determines capillary hydrostatic pressure P_c ?

- ↓ Arterial pressure ↓ P_c
- ↓ Venous volume (pressure) ↓ P_c **
- Closure of arteriole ↓ P_c
- Closure of a venule ↑ P_c
- Local arteriolar vasoconstriction ↓ P_c
- Local venoconstriction ↑ P_c

Localized arteriolar vasodilation/vasoconstriction



Normal Balance



Arterial end **Venous end**

Arterial end	Venous end
Hydro - Osmo = ?	Hydro - Osmo = ?
(35-0) - (28-3) =10 fil	(15-0) - (28-3) = -10 abs

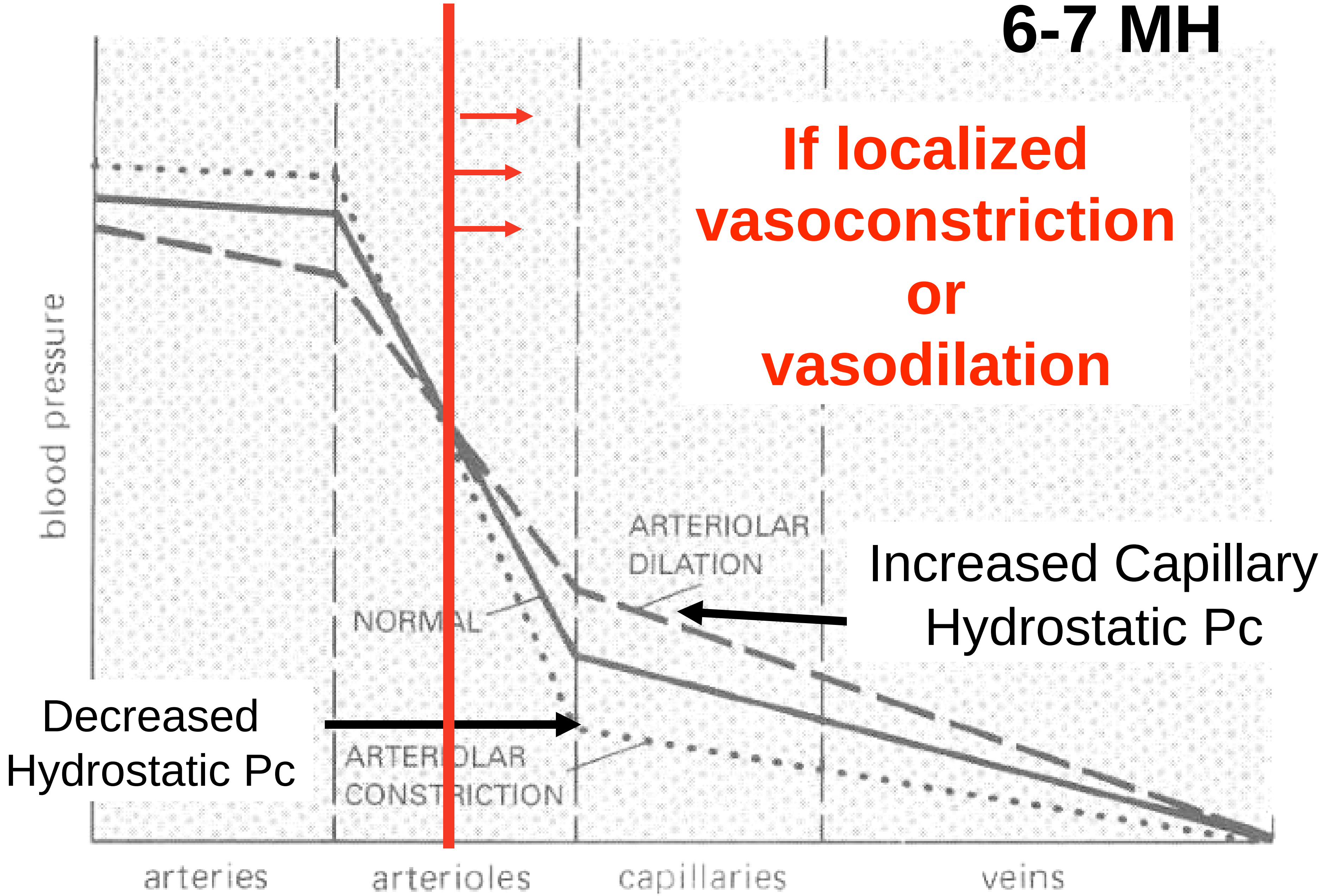
Then Constrict Arterioles & decrease capillary pressure

Arterial end	Venous end
Hydro - Osmo = ?	Hydro - Osmo = ?
(25-0) - (28-3) = 0	(5-0) - (28-3) = -20 abs

Reduced filtration

Interstitial Absorption

6-7 MH

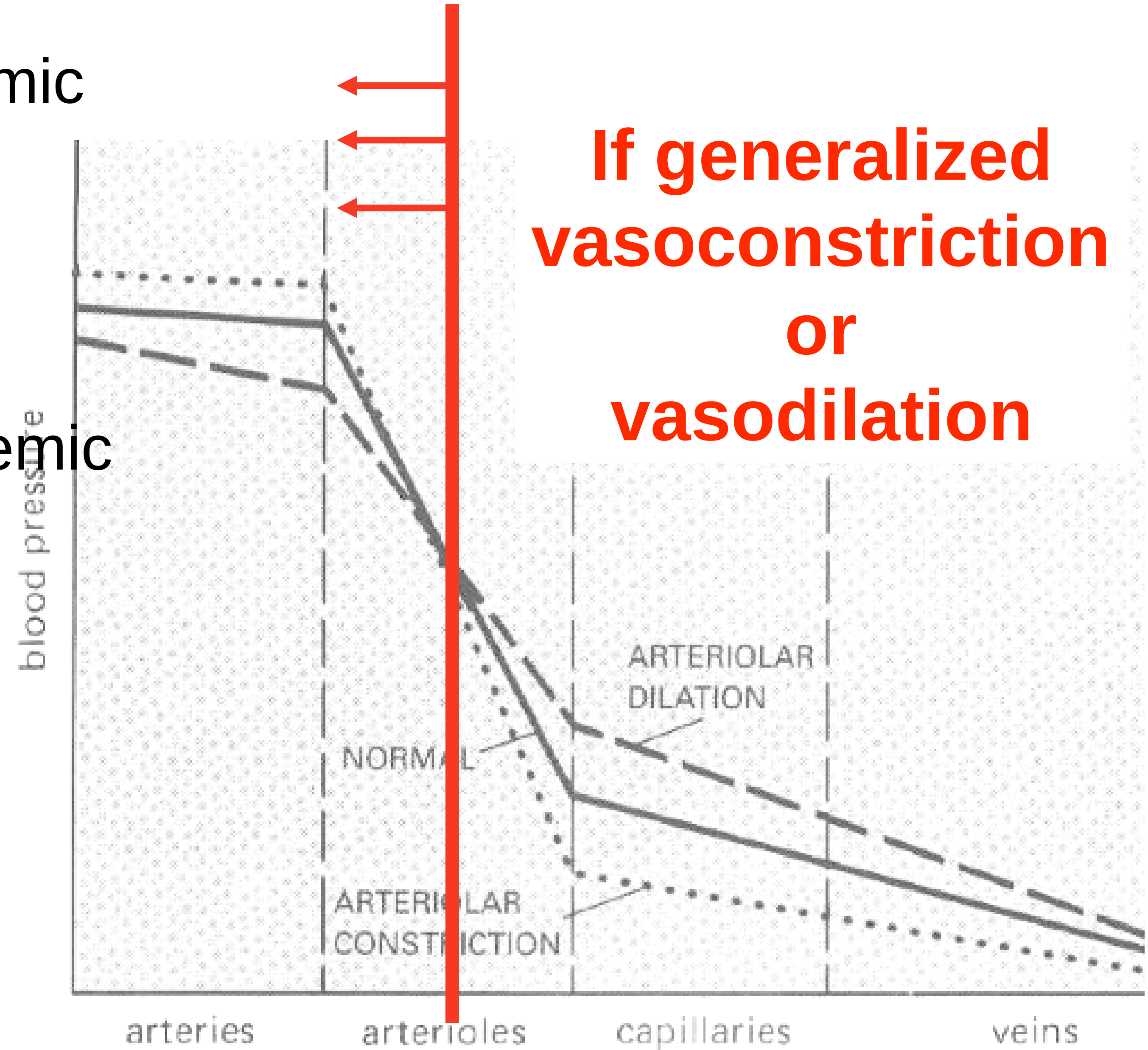


 Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.

Figure 6-7 Effect of changes in arteriolar resistance on vascular pressures

Increased Systemic Pressure

Decreased Systemic Pressure



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6-7 MH

Arterial Baroreceptor Reflex(s)

-minimize changes in arterial blood pressure

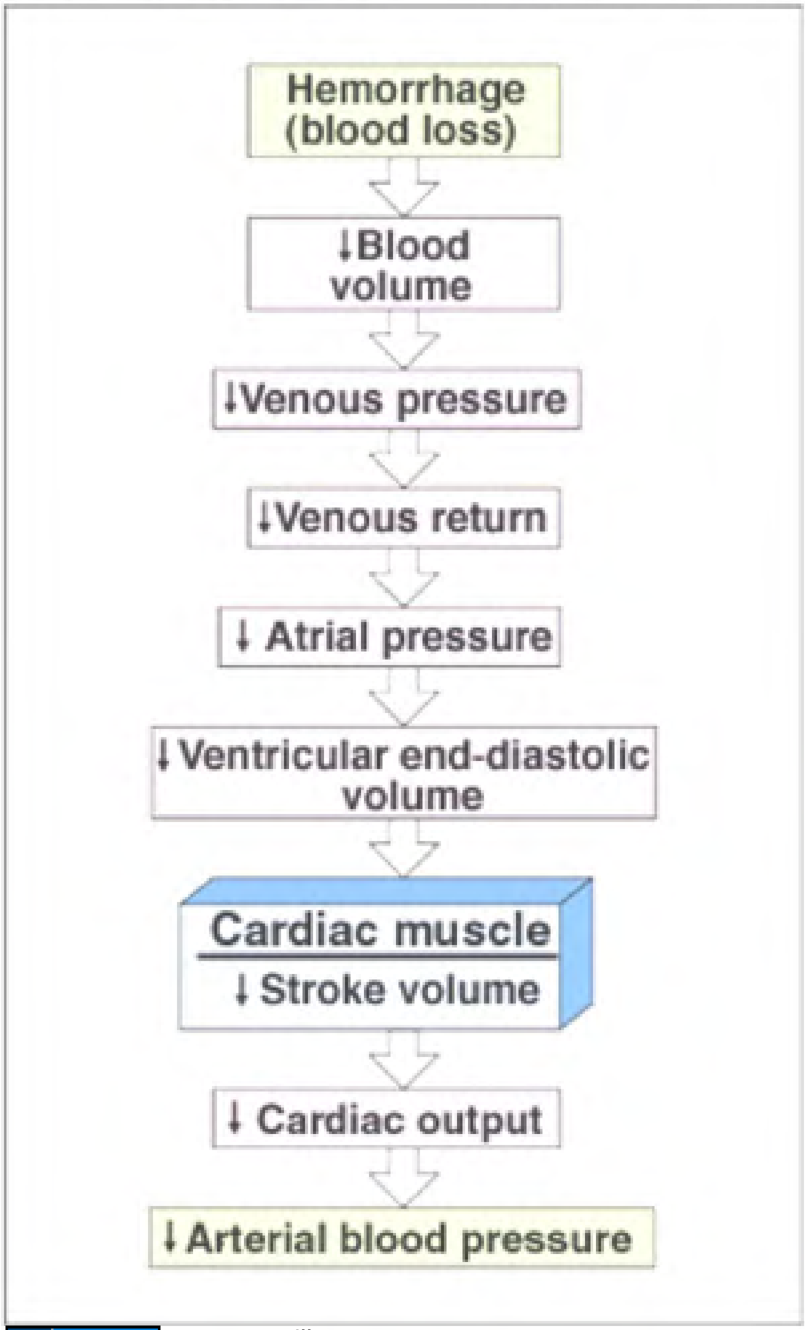
- tend to restore MAP to initial value

- moves pressure opposite disturbance

- utilizes (controls) HR, SV, TPR, “other” changes

- can be over ridden by other reflexes and controls

Decrease in blood volume



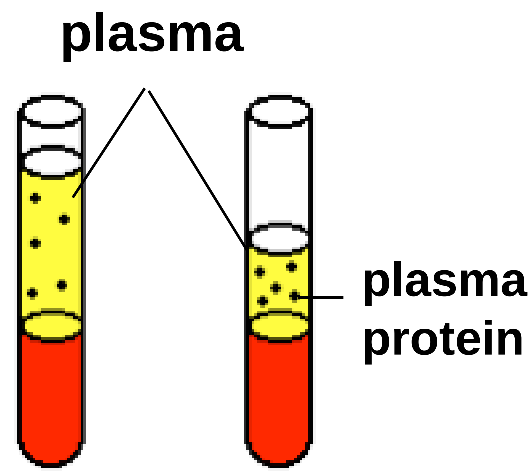
But

OTHER

VOLUME

LOSSES

OTHER FLUID LOSS - diarrhea or sweating



fluid loss

↓

↓ **extracellular fluid volume**

↓

↓ **plasma volume**

↓ P_c ↑ COP_p **due to loss of plasma water**

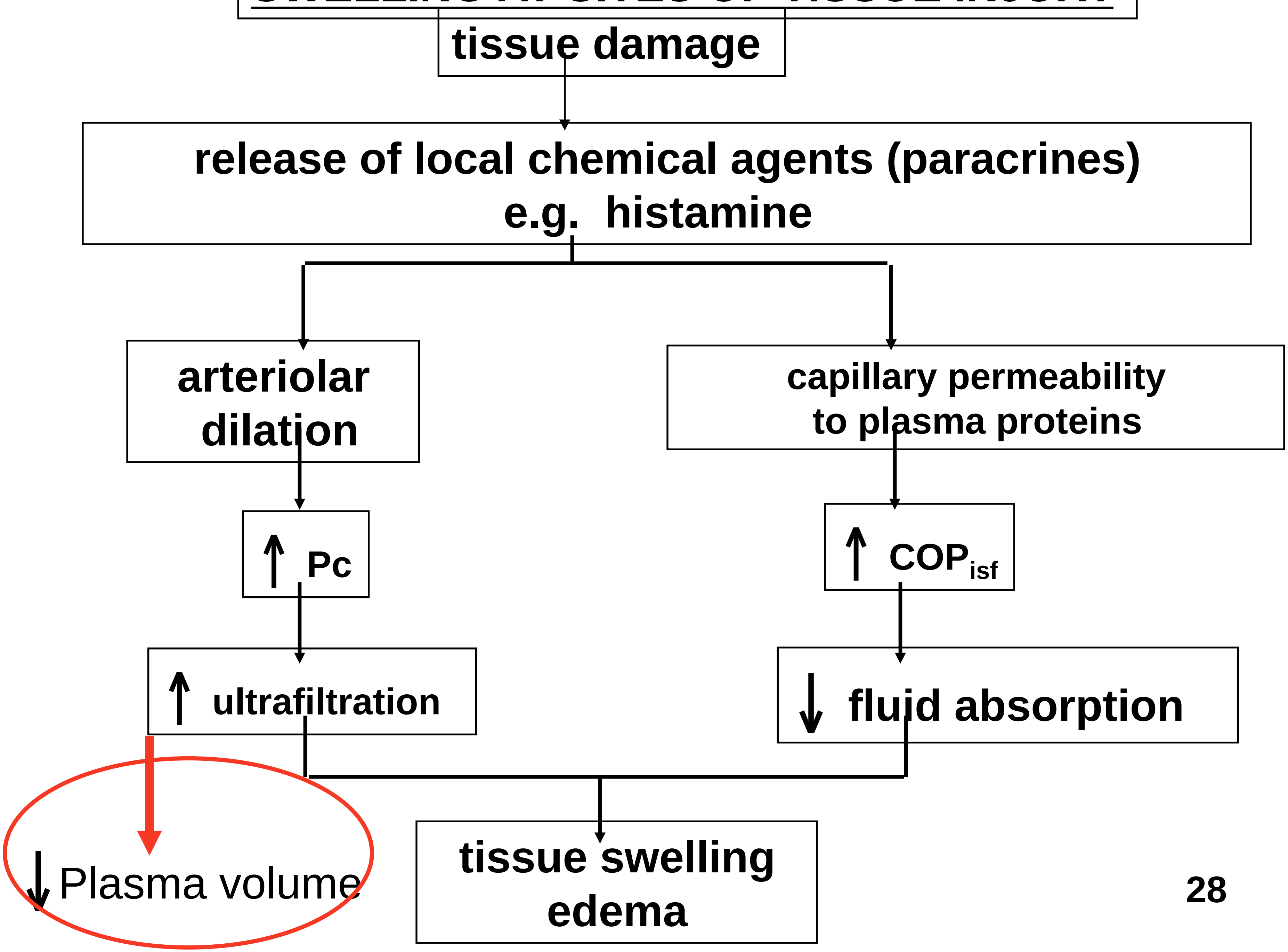
↓

↑ **absorption of interstitial fluid**

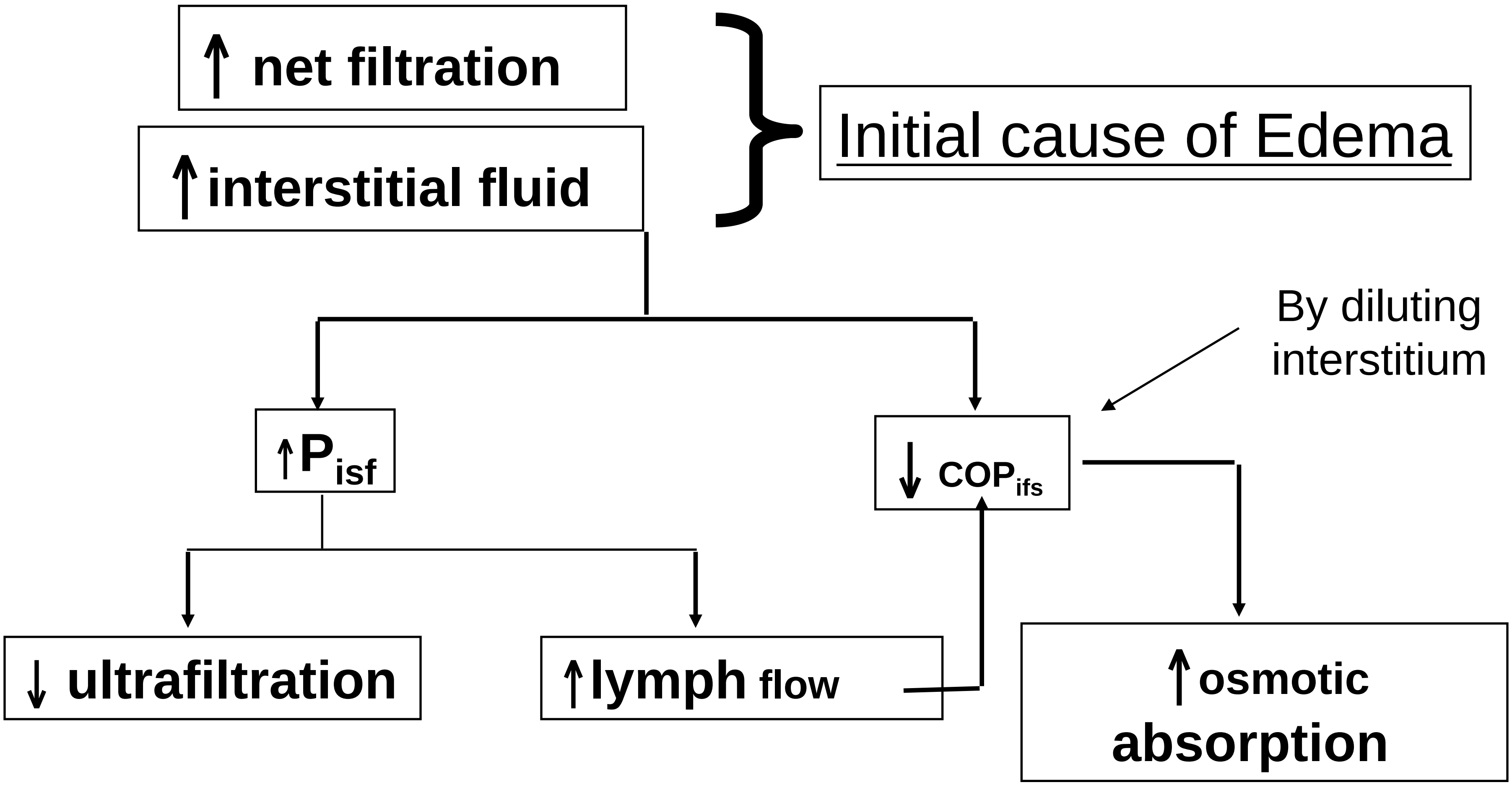
↓

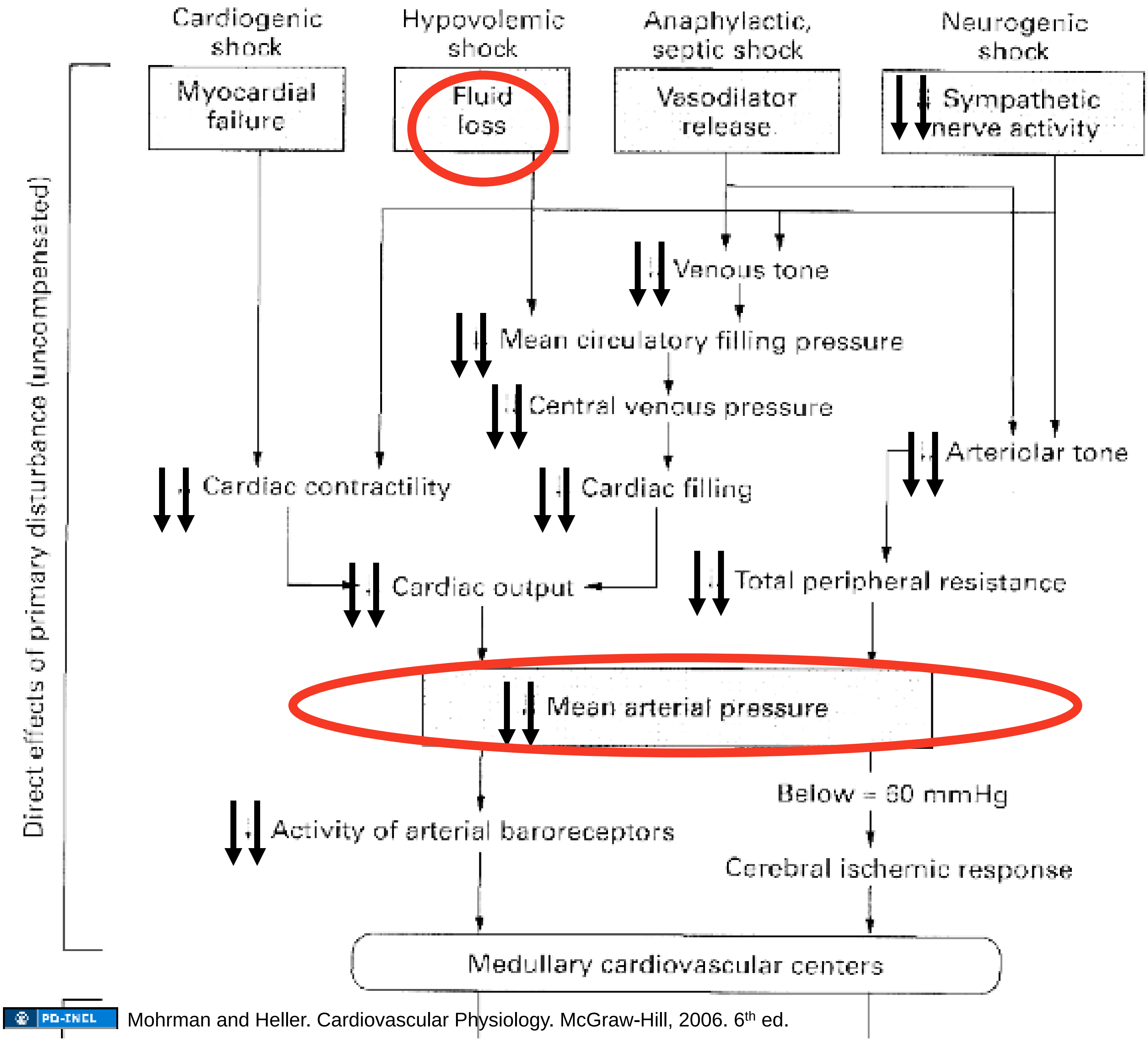
partial restoration of plasma volume

SWELLING AT SITES OF TISSUE INJURY



INTERSTITIAL FACTORS OPPOSING EDEMA (& PLASMA LOSS)





M&H 11-1

 Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.

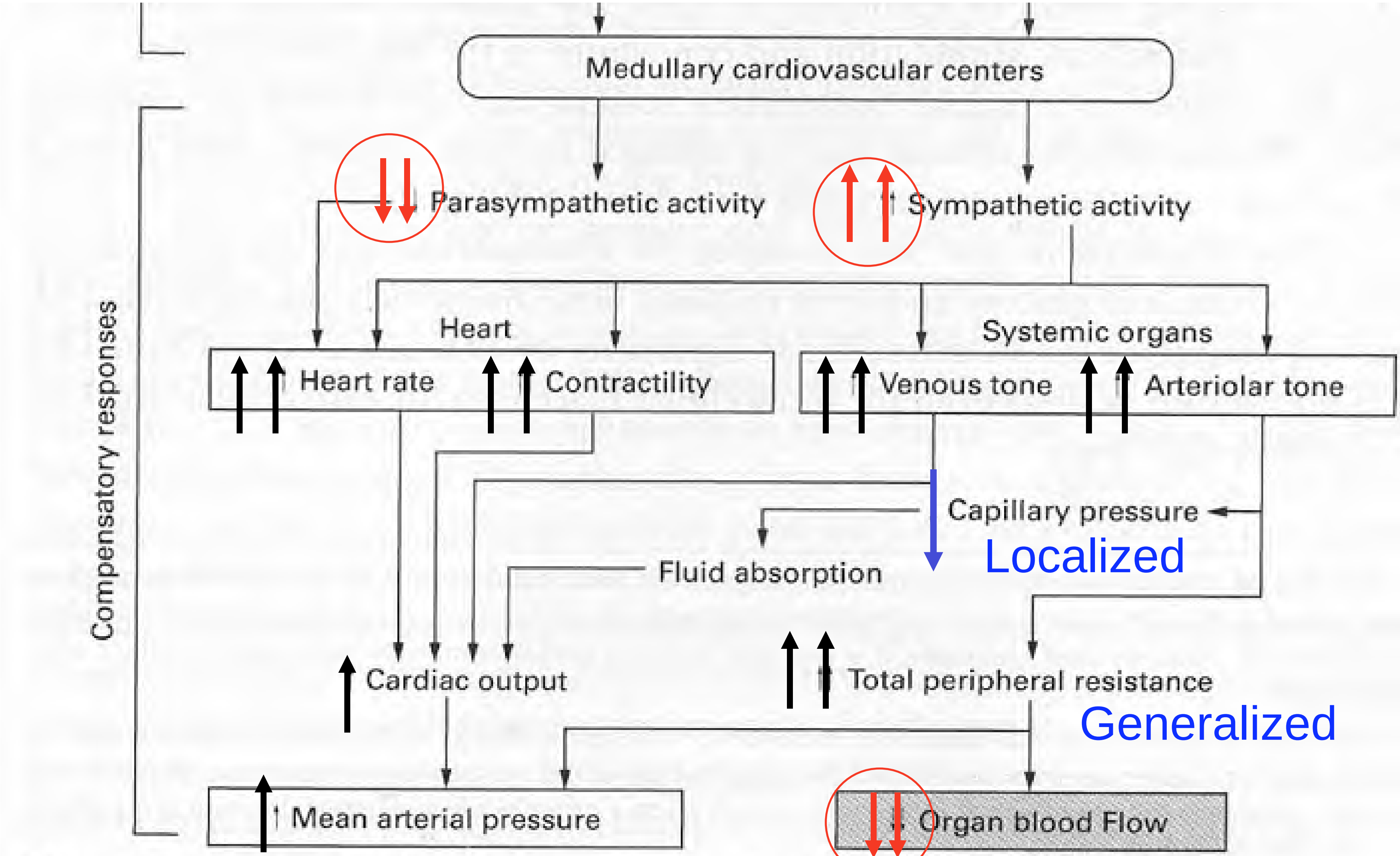
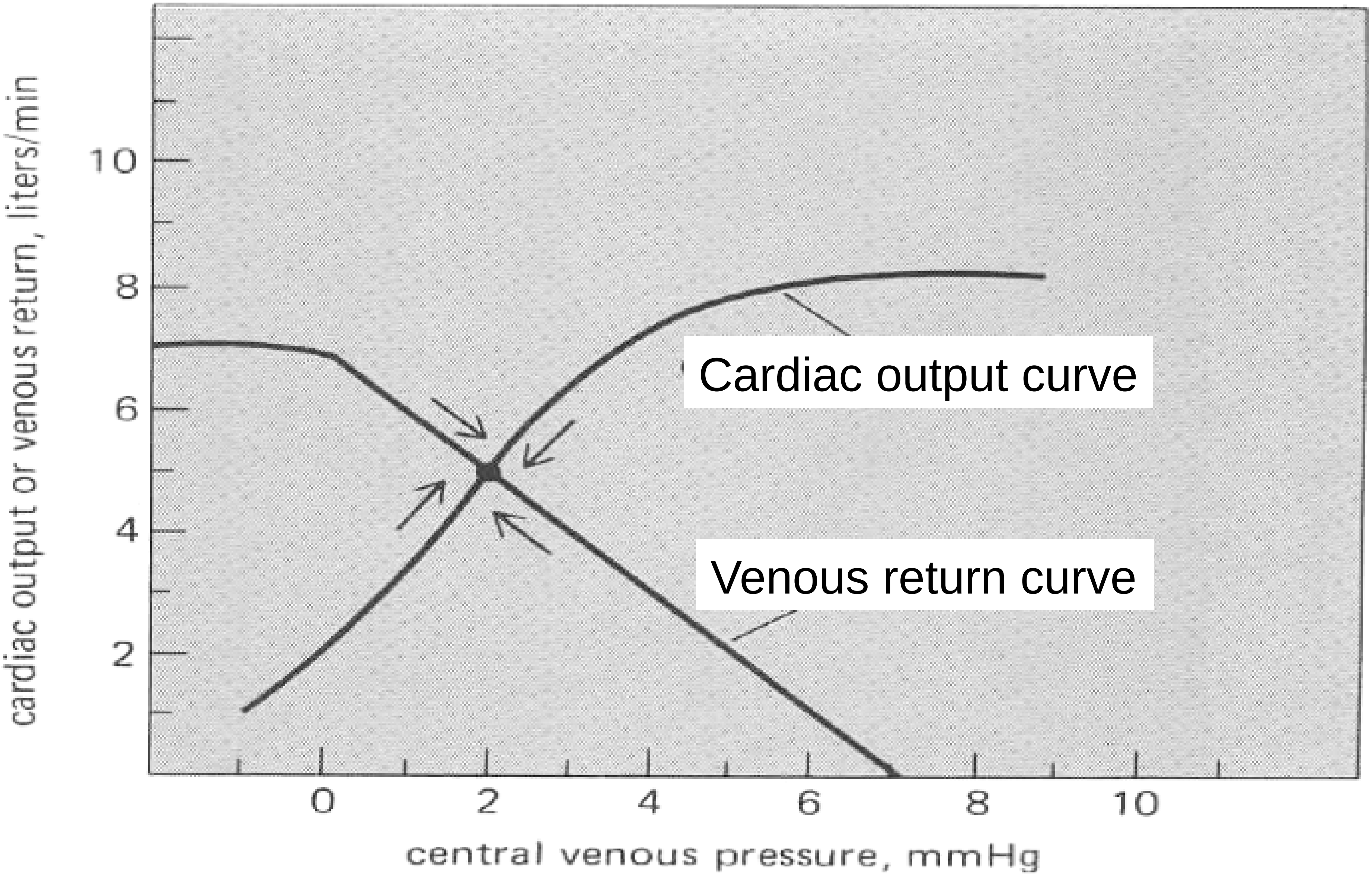


Figure 11–1. Cardiovascular alterations in shock.

Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.



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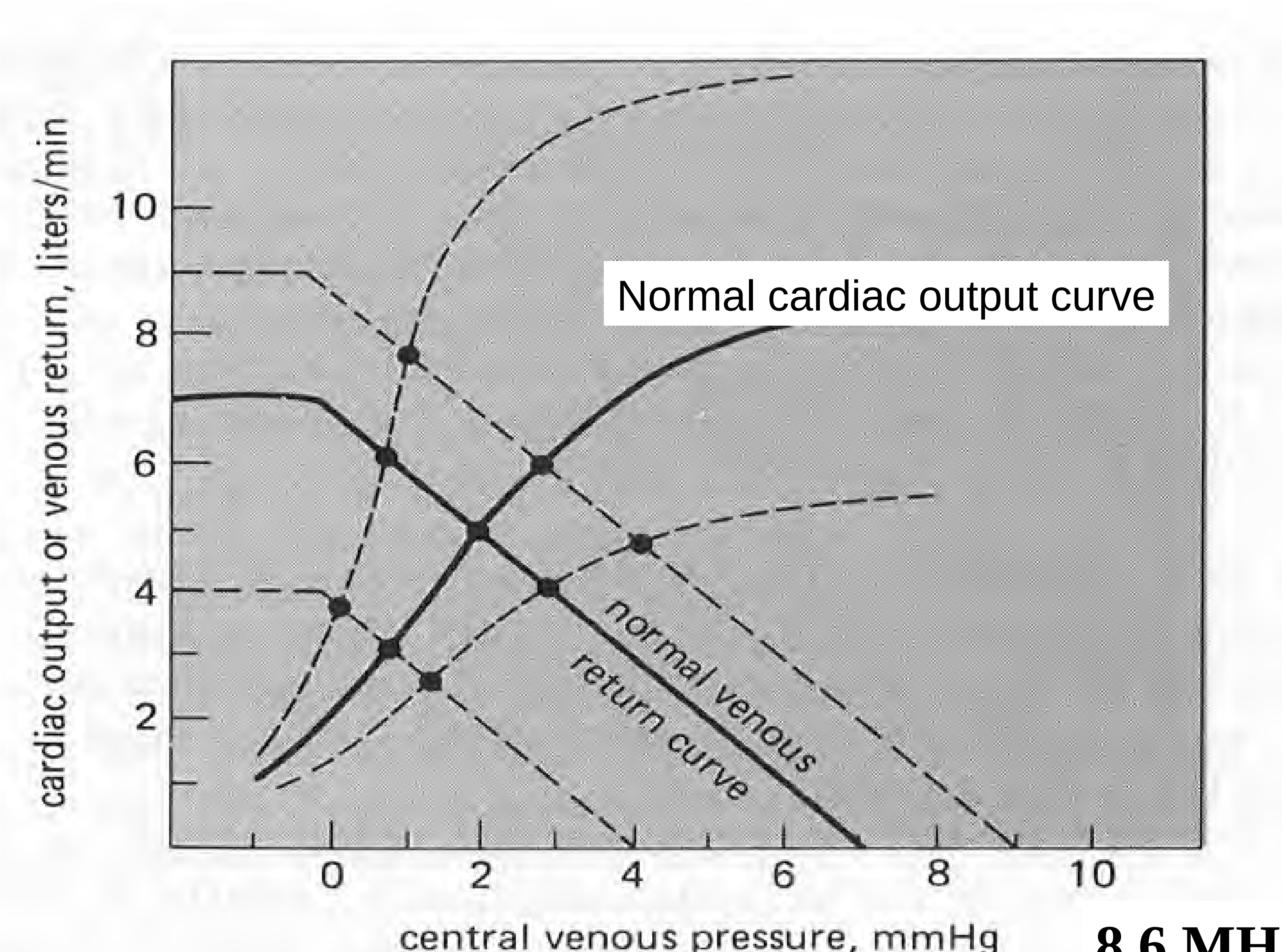
8.5 MH



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8.6 MH

Some Hemorrhage Responses

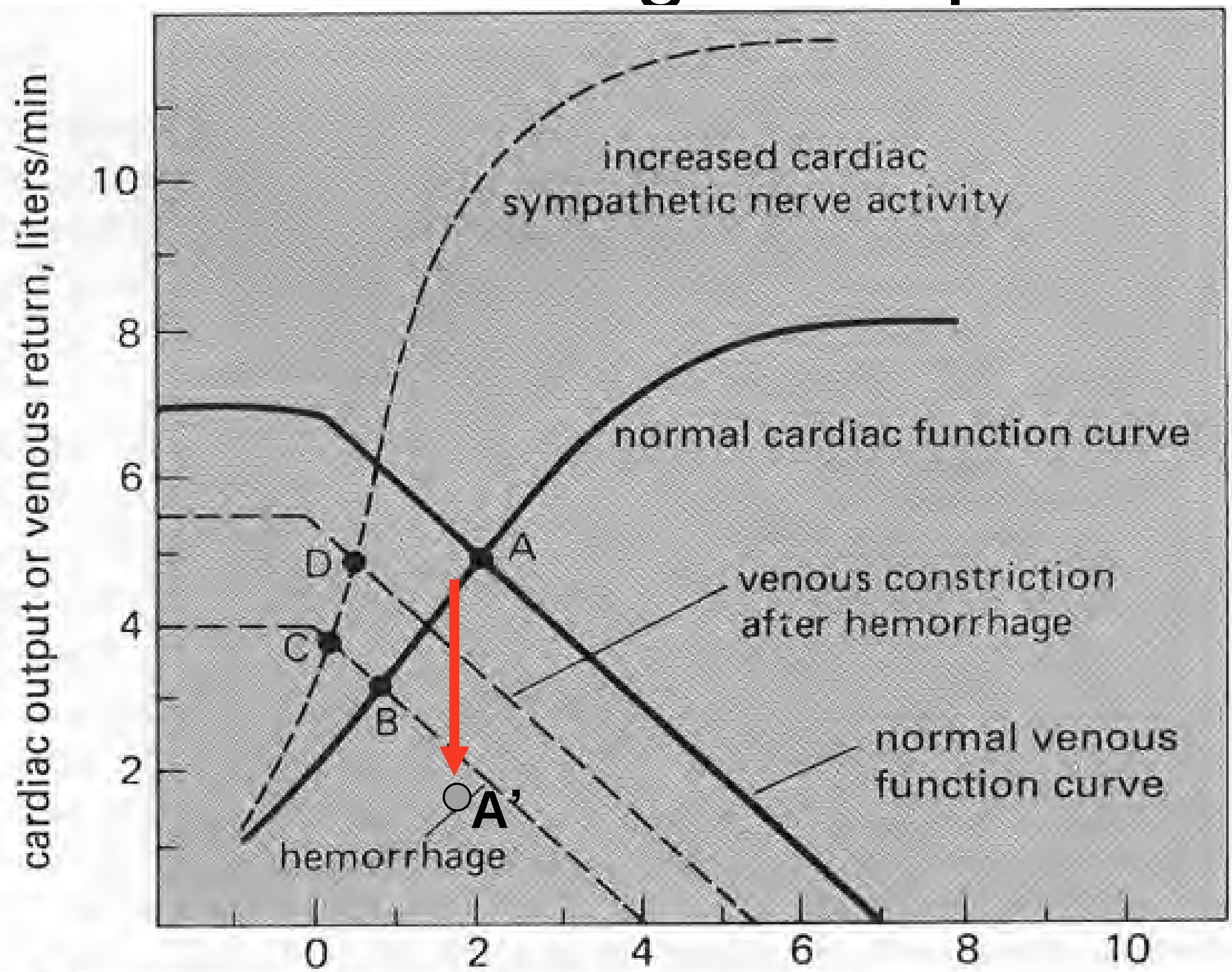

Figure 8–7: Cardiovascular adjustments to hemorrhage.

 Mohrman and Heller. Cardiovascular Physiology. McGraw-Hill, 2006. 6th ed.

Hemorrhage on VR and CO curves 1

	CVP	VR	CO	
A	2 mmHg	5L /min	5L /min	Original curves

Hemorrhage shifts to new “hemorrhage” VR curve and momentarily unbalances system.

A’	**2 mmHg**	**2L /min**	**5L /min**	**Unstable (imaginary)**

central pool emptying and lowering CVP from 2 to 1 mmHg on

“Hem “ VR curve brings you to B

Hemorrhage on VR and CO curves 2

	CVP	VR	CO	
B	1mmHg	3 L/min	3 L/min	new stable state WITHOUT reflex compensations.

The reduced CO lowers MAP, triggers arterial baroreceptor reflex and first step (illustrated) is positive inotropic and chronotropic effects on heart. This shifts you to a new CO function curve and further empties CV pool.

You move along the VR curve from B to C

Hemorrhage on VR and CO curves 3

	CVP	VR	CO
C	0.3mmHg	4 L /min	4L /min

Compensation further lowers CVP increasing VR and partially restores CO with SV and HR increases.

D	0.5mmHg	4.5L /min	4.5L /min

Venoconstriction shifts to a new VR curve and new stable point.

Even with near immediate baroreceptor reflex compensations the system still has not fully compensated. The heart is being autonomically (sympathetic and parasympathetic) driven, peripheral vessels are constricted and this is a **temporary "fix".**

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