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Author(s): Louis D'Alecy, D.M.D., Ph.D., 2009

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M2 Mini Review
August 2008
Normal Cardiac Cycle

Targeted to Bridge
Mohrman & Heller per M1 and
Lilly 4th ed. per M2
Yes -- it is the ~ same as last year -- it is a REVIEW

Louis G. D'Alecy, Professor of Physiology

Normal Cardiac Cycle Outline 1

BEFORE LUNCH

1) Pressure Flow Circulation
2) Systole vs. Diastole
3) Cardiac Cycle Pressure Gradients
4) Heart Rate
    - Normal
    - Fast
    - Slow
    - Origins & pathway through heart

Normal Cardiac Cycle Outline 2

AFTER LUNCH

1) Stroke Volume
   - Preload
   - Afterload
   - Contractility
2) LV Pressure-Volume Loops
3) Measuring pressures CVP, RV, PAP, PCWP,LVEDP
4) Measuring Cardiac Output

Heart is a Pressure Pump but also pumps FLOW (volume/time)

Heart Rate X Stroke volume =

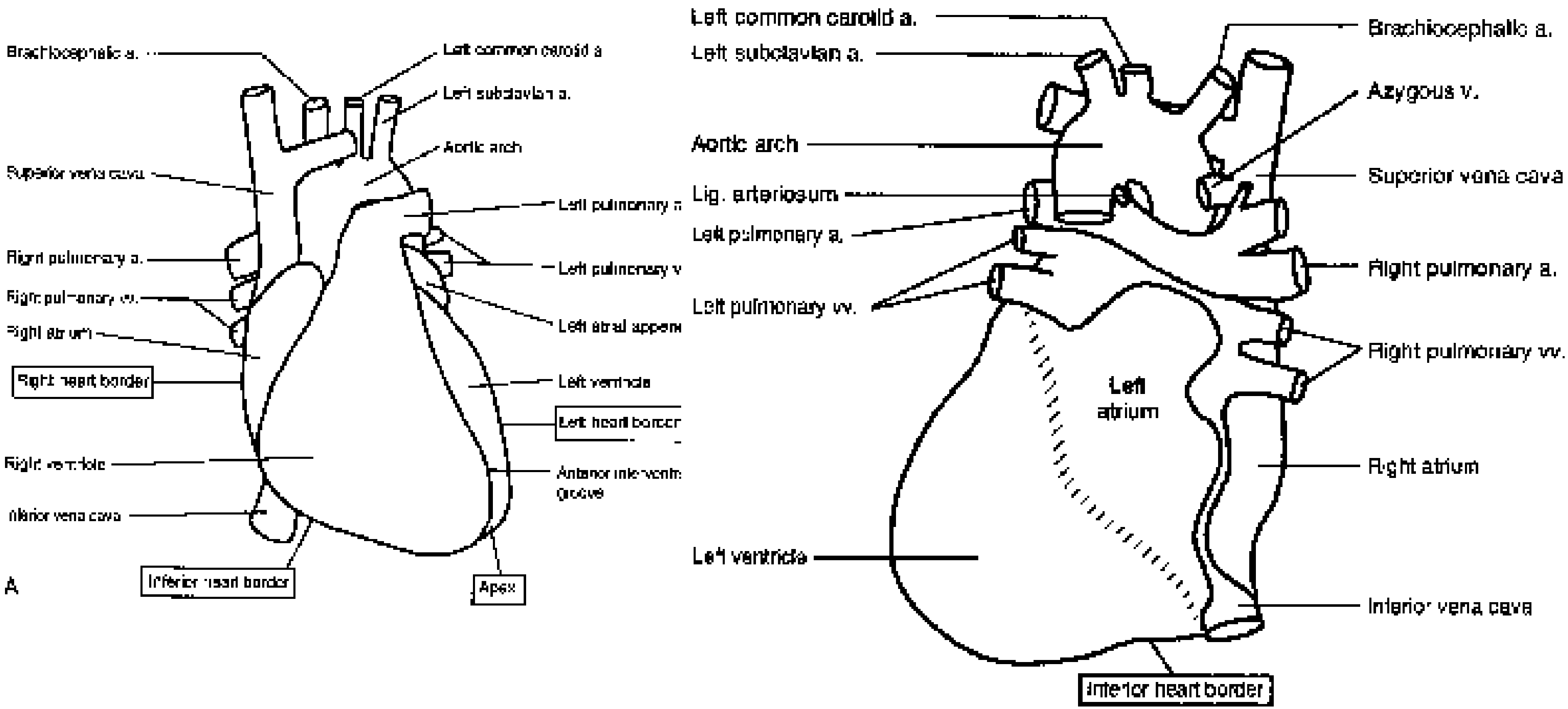
Cardiac Output

HR X SV = CO

b /min X mL /b = mL /min or L/min

Requirements for Effective Cardiac Pumping

1 Synchronized	not arrhythmic
2 Valves open fully	not stenotic
3 Valves don't leak	not insufficient or regurgitant
4 Forceful	not failing
5 Must fill	Not "dry"

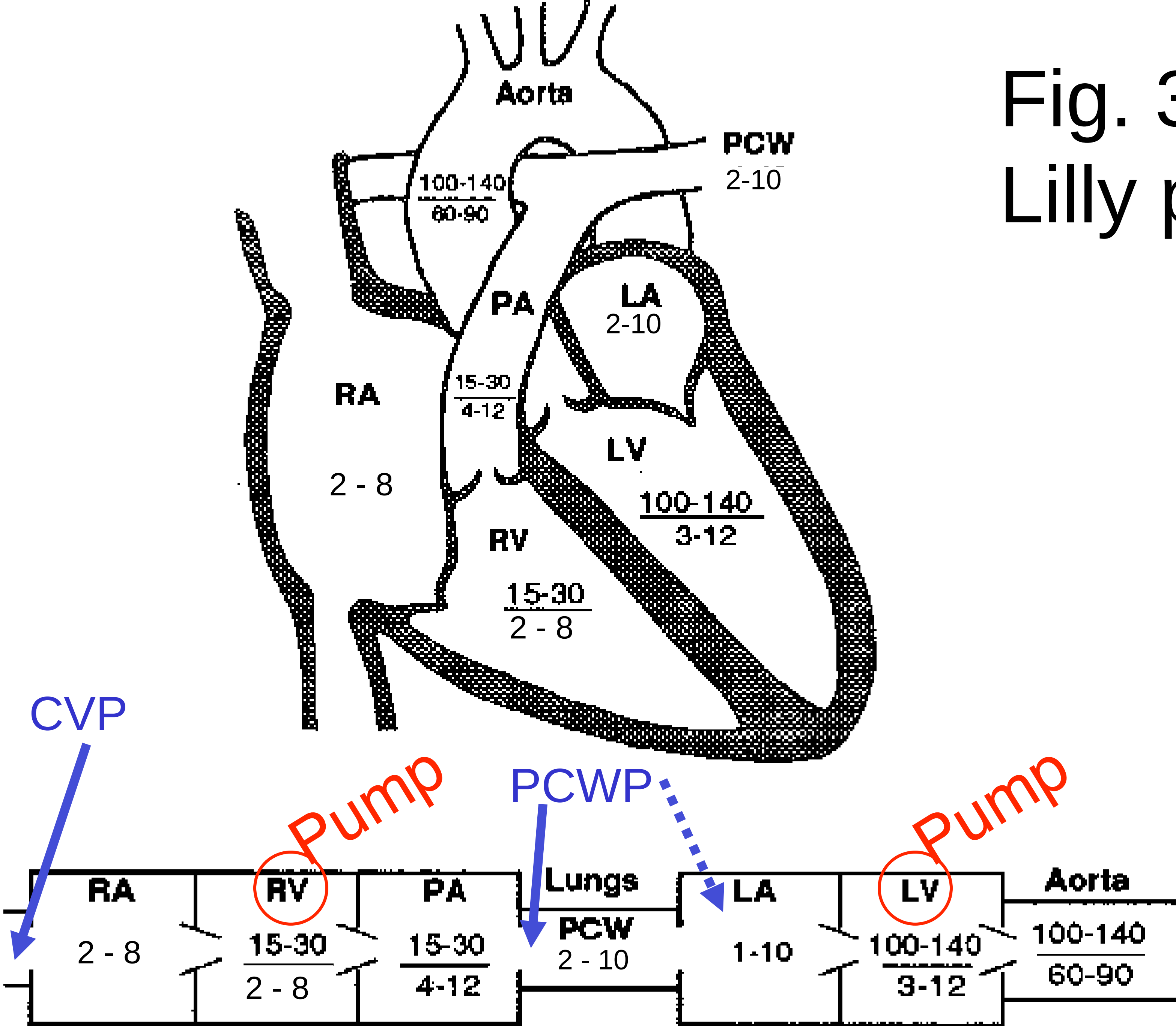


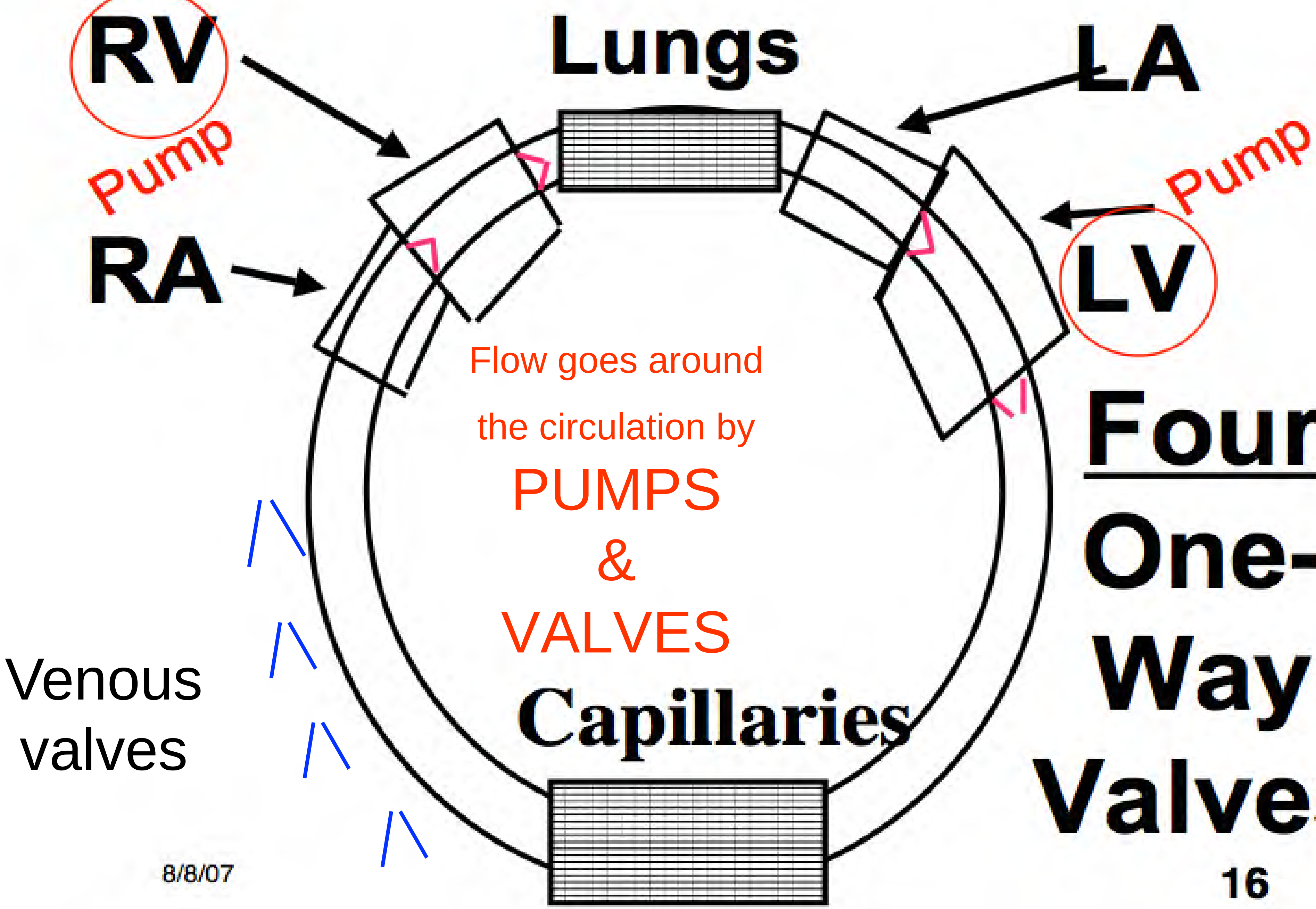
Anterior

Posterior

Fig 1.2 Lilly

Fig. 3.14
Lilly p 61




RV
Pump
RA
Lungs
LA
Pump
LV
Flow goes around
the circulation by
PUMPS
&
VALVES
Capillaries
Four
One-
Way
Valve
Venous
valves

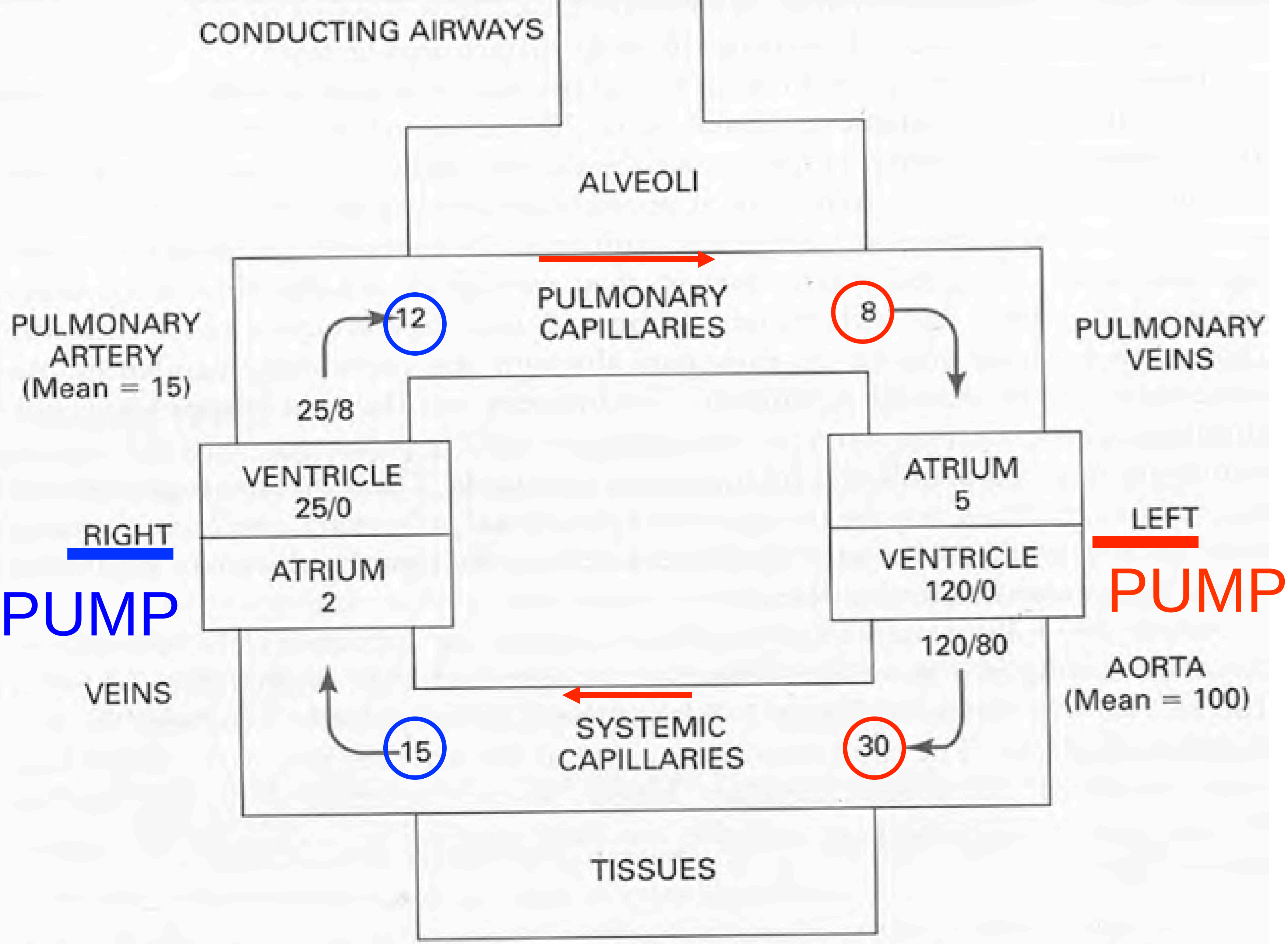


Figure 4–1. Pressures, expressed in mm Hg, in the systemic and pulmonary circulations.

Pressure gradient from <u>beginning to end</u> of capillaries

- Pulmonary capillaries
- Arterial end 12 mmHg
- Venous end 8 mmHg

4 mmHg

- Systemic capillaries
- Arterial end 30 mmHg
- Venous end 15 mmHg

15 mmHg

From Levitzky , Fig 4-1

Systole & Diastole

Text books vary in definitions but most the common use of the unmodified terms “systole” and “diastole” is:

Systole is the period from the closing of the atrio-ventricular valve (mitral) to the closing of the aortic valve (ventricular contraction).

Diastole is the period from the closing of the aortic valve to the closing of the atrio-ventricular valve (ventricular relaxation and filling).

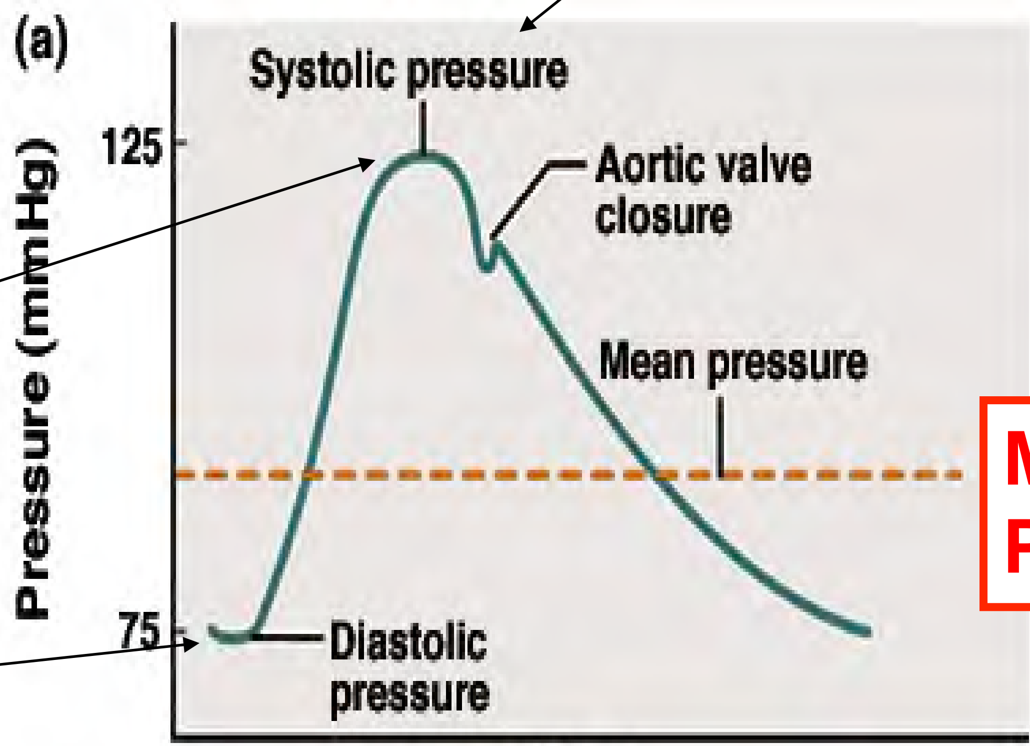
EXTRA NOTE: Some more rigorous texts distinguish ventricular systole from arterial systole:

Ventricular systole is the period from the closing of the atrio-ventricular valve (mitral) until its opening.

Arterial systole is the period from the opening of the aortic valve until its closing.

Arterial pressure

1



2

4

MAP = P_d + 1/3Pp

PD-INEL Source Undetermined

Time

3 Pulse Pressure = (Systolic − Diastolic)

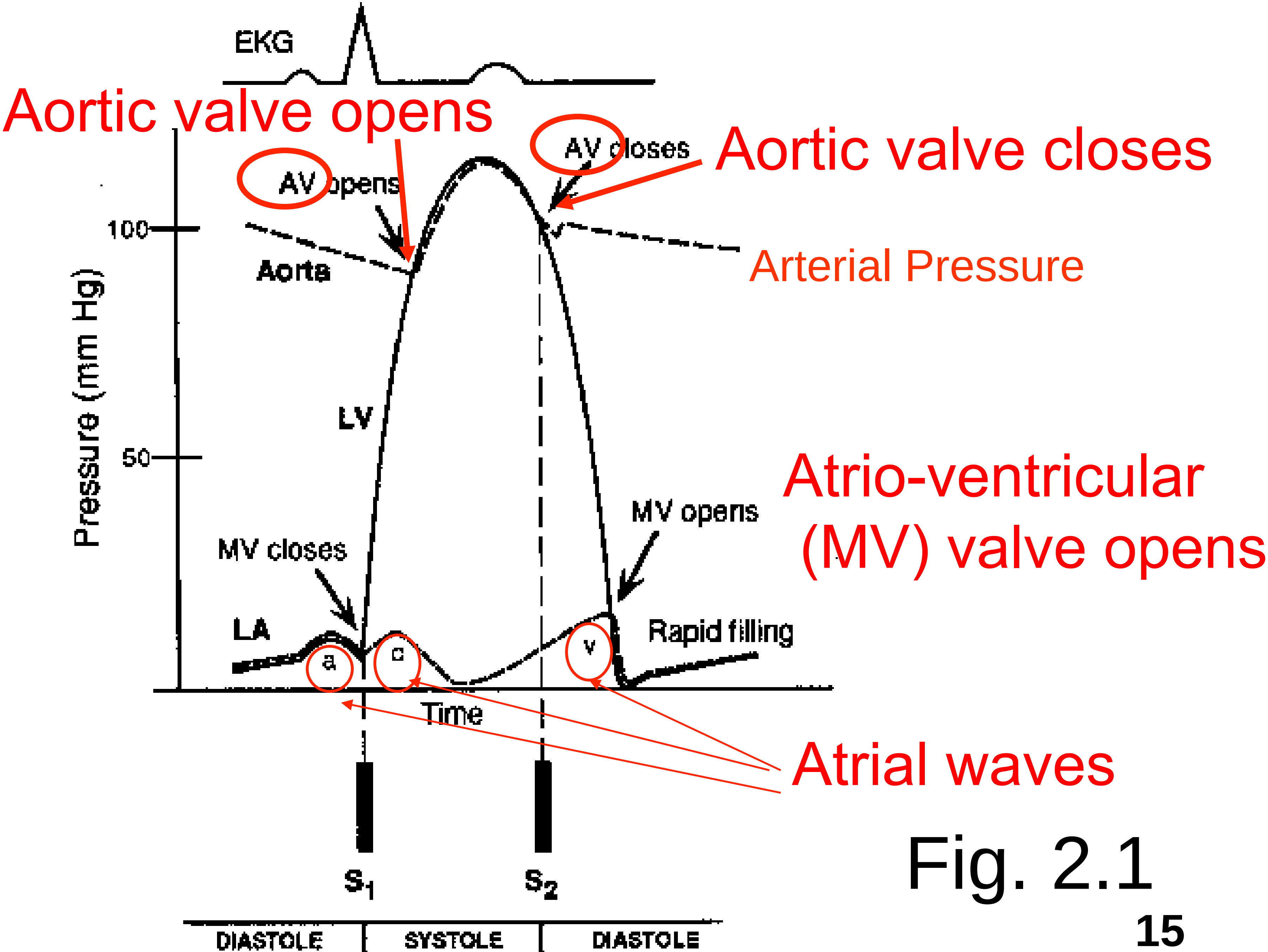
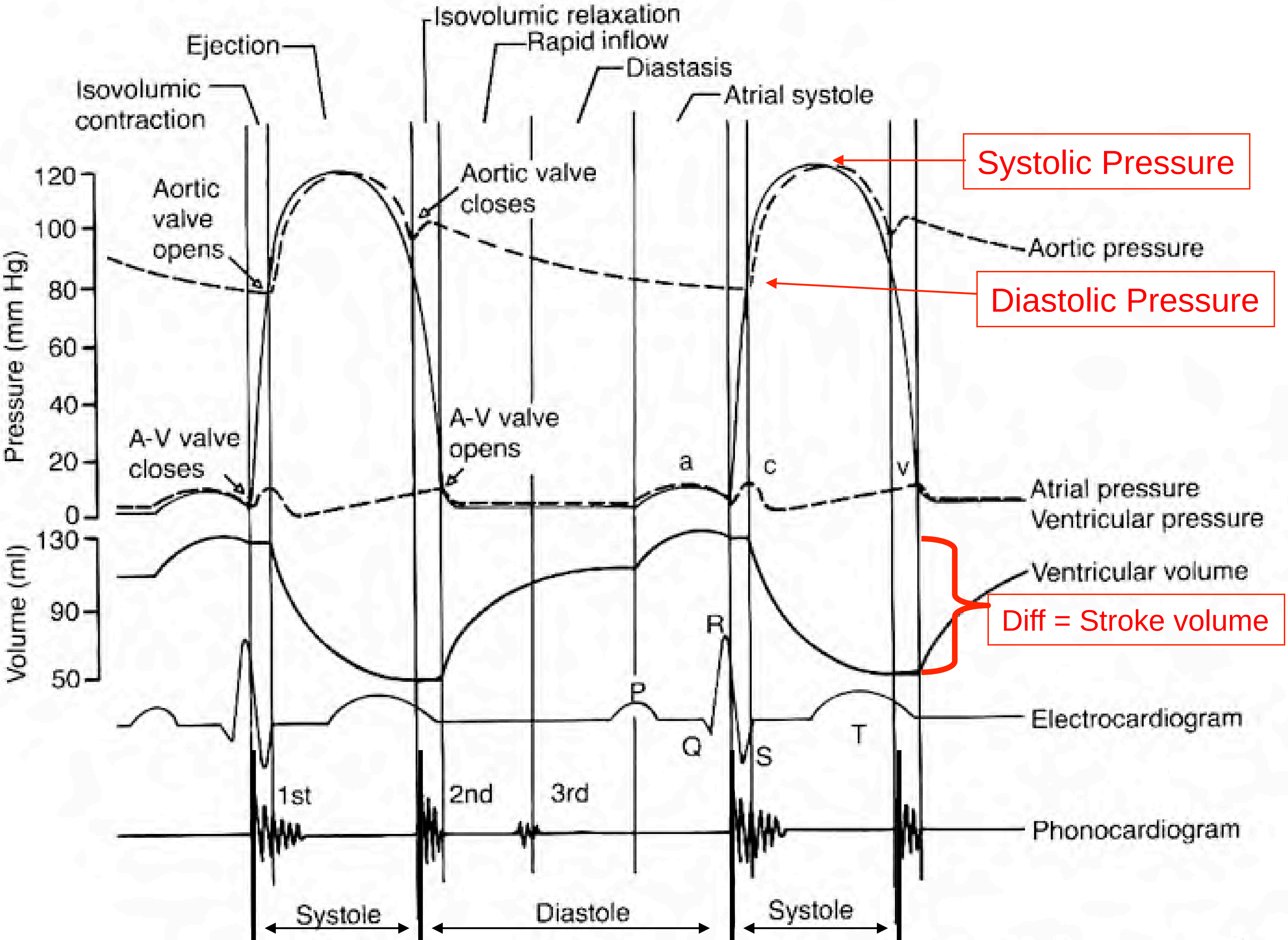

EKG
Aortic valve opens
AV opens
Aortic valve closes
AV closes
100
Aorta
Arterial Pressure
Pressure (mm Hg)
LV
50
Atrio-ventricular
(MV) valve opens
MV opens
MV closes
LA
Rapid filling
a
c
v
Time
Atrial waves
S_1
S_2
DIASTOLE
SYSTOLE
DIASTOLE

Fig. 2.1



Isovolumic relaxation
Rapid inflow
Ejection
Diastasis
Isovolumic contraction
Atrial systole
Systolic Pressure
120
100
80
60
40
20
0
Pressure (mm Hg)
Aortic valve opens
Aortic valve closes
Aortic pressure
Diastolic Pressure
A-V valve closes
A-V valve opens
a
c
v
Atrial pressure
Ventricular pressure
130
90
50
Volume (ml)
Ventricular volume
Diff = Stroke volume
R
P
Q
S
T
Electrocardiogram
1st
2nd
3rd
Phonocardiogram
Systole
Diastole
Systole

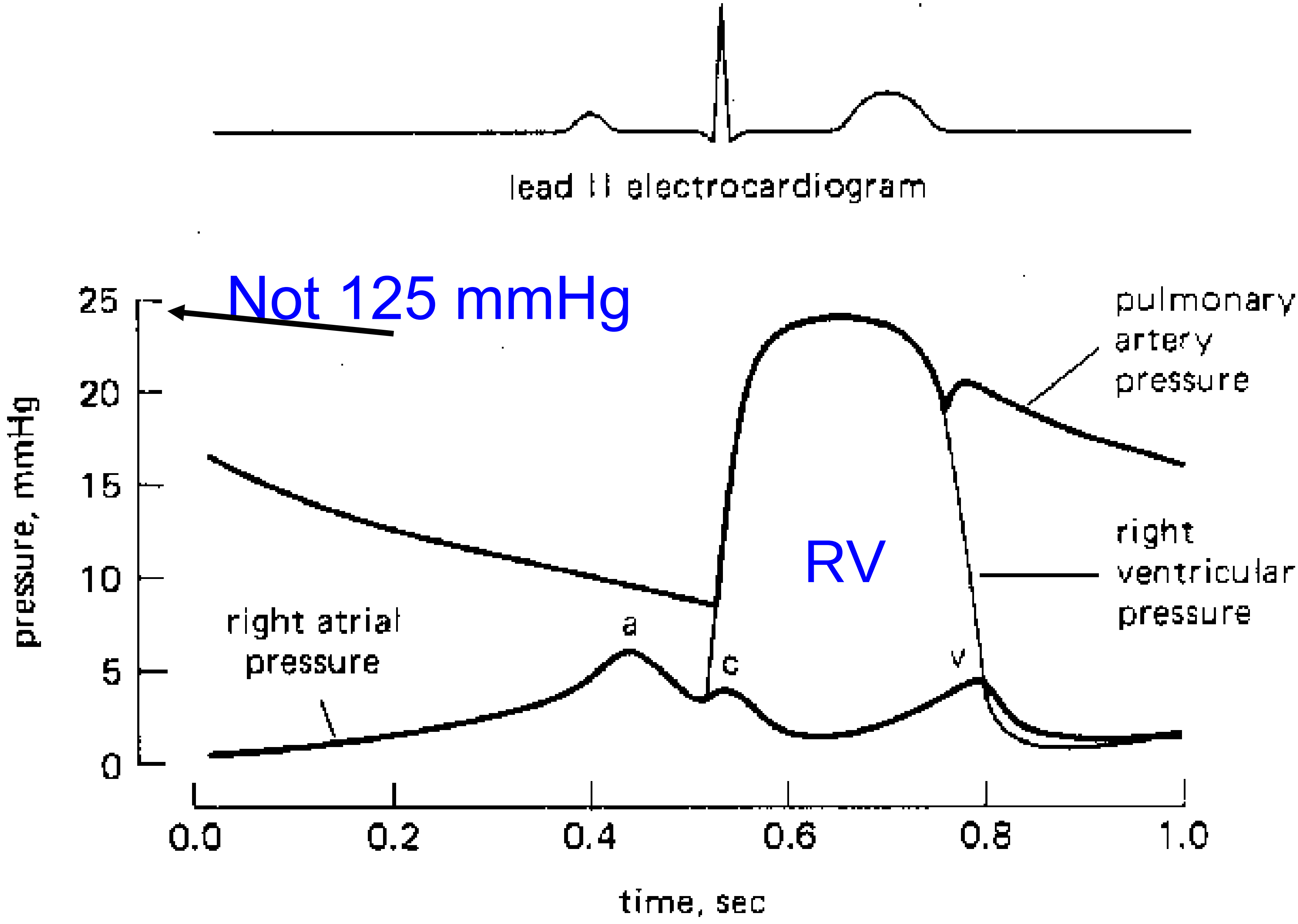


Figure 4-2 Cardiac cycle—right heart.

Heart is a Pressure Pump but also pumps FLOW (volume/time)

Heart Rate X Stroke volume =

Cardiac Output

HR X SV = CO

b /min X mL /b = mL /min or L/min

Origins of the Heart Beat

- Automaticity: the ability to initiate its own beat.
- Rhythmicity: regularity of pace-making activity.
- Pacemaker: the region of the heart that ordinarily generates impulses at the greatest frequency.
- Sinoatrial (SA) node: normal, main pacemaker.
- Intrinsic rate: ~100b/minute for SA node
  - vs. resting rate
- Ectopic foci or pacemakers: regions other than SA node that initiate beat.

Variations in the Heart Rate (fast)

- Tachycardia: heart rate greater than normal.
  - Sinus tachycardia: a heart rate greater than normal (> 100b/min) from SA node.
  - Ectopic tachycardia: a heart rate greater than normal originating from ectopic focus.
  - Paroxysmal tachycardia: a heart rate greater than normal originating from ectopic focus that begins and ends abruptly.

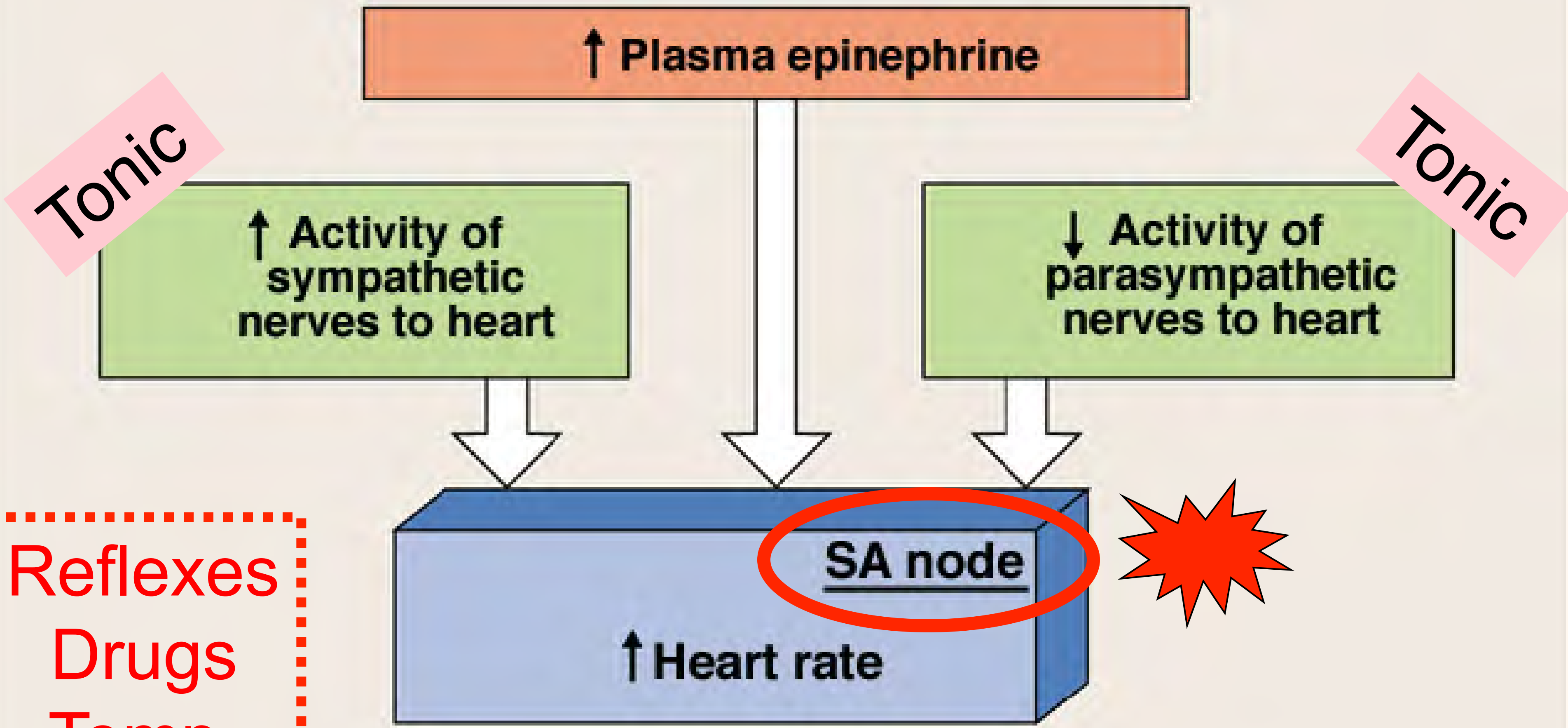
Variations in the Heart Rate (slow)

- Bradycardia: a heart rate less than normal.
  - Sinus bradycardia: a heart rate less than normal (< 60 beats/minute) from SA node.
  - Idiojunctional Rhythm: AV nodal rhythm when SA node fails. 40-60 b/minute
  - Idioventricular Rhythm: Ectopic ventricular rhythm when SA & AV nodes fails. 20-40 b/ minute

Factors influencing heart rate

Effector Pathways

+ or - CHRONOTROPIC



Reflexes
Drugs
Temp.

Phase 4 = relatively more Na^+ going in and less K^+ going out thus +++

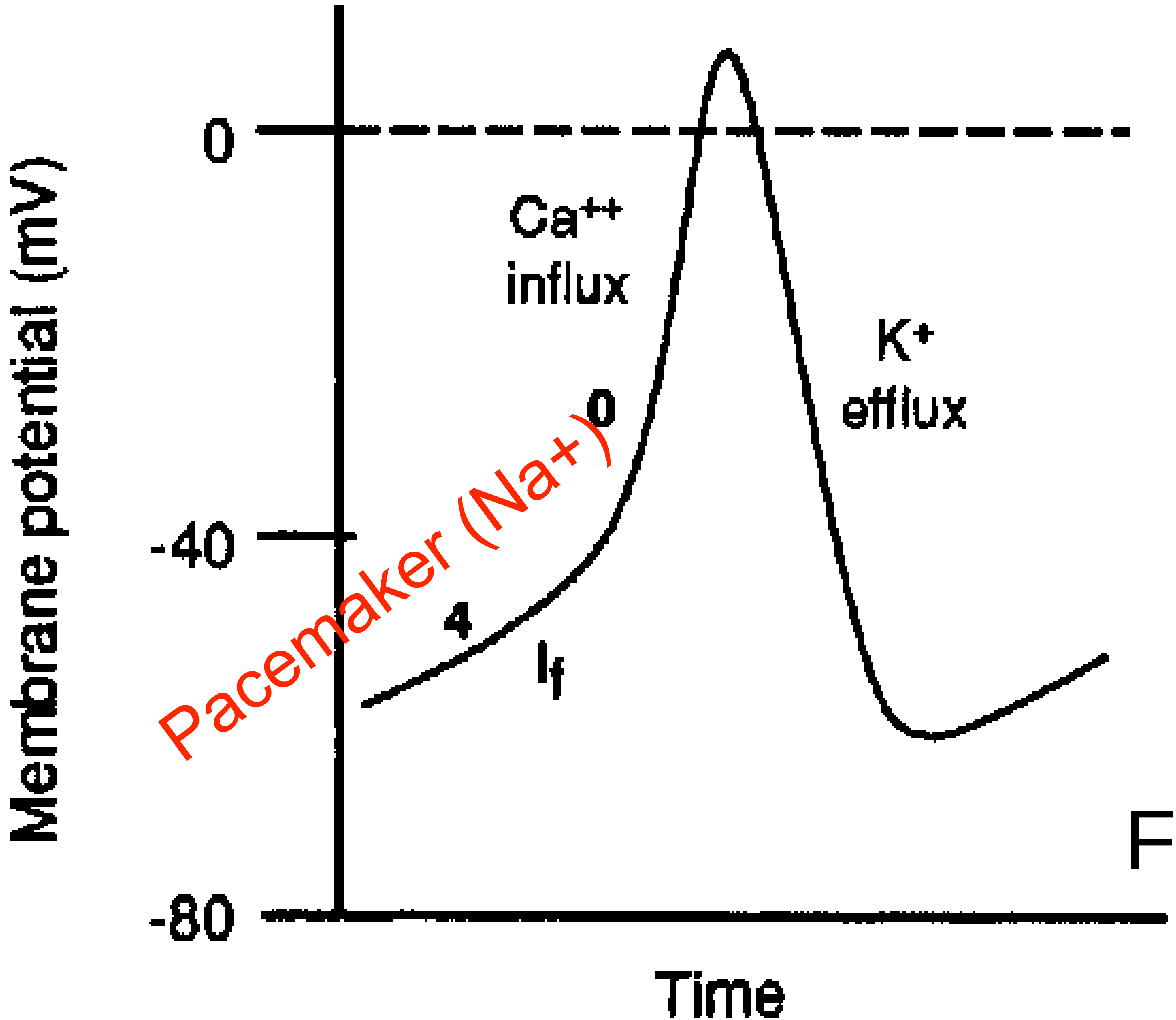
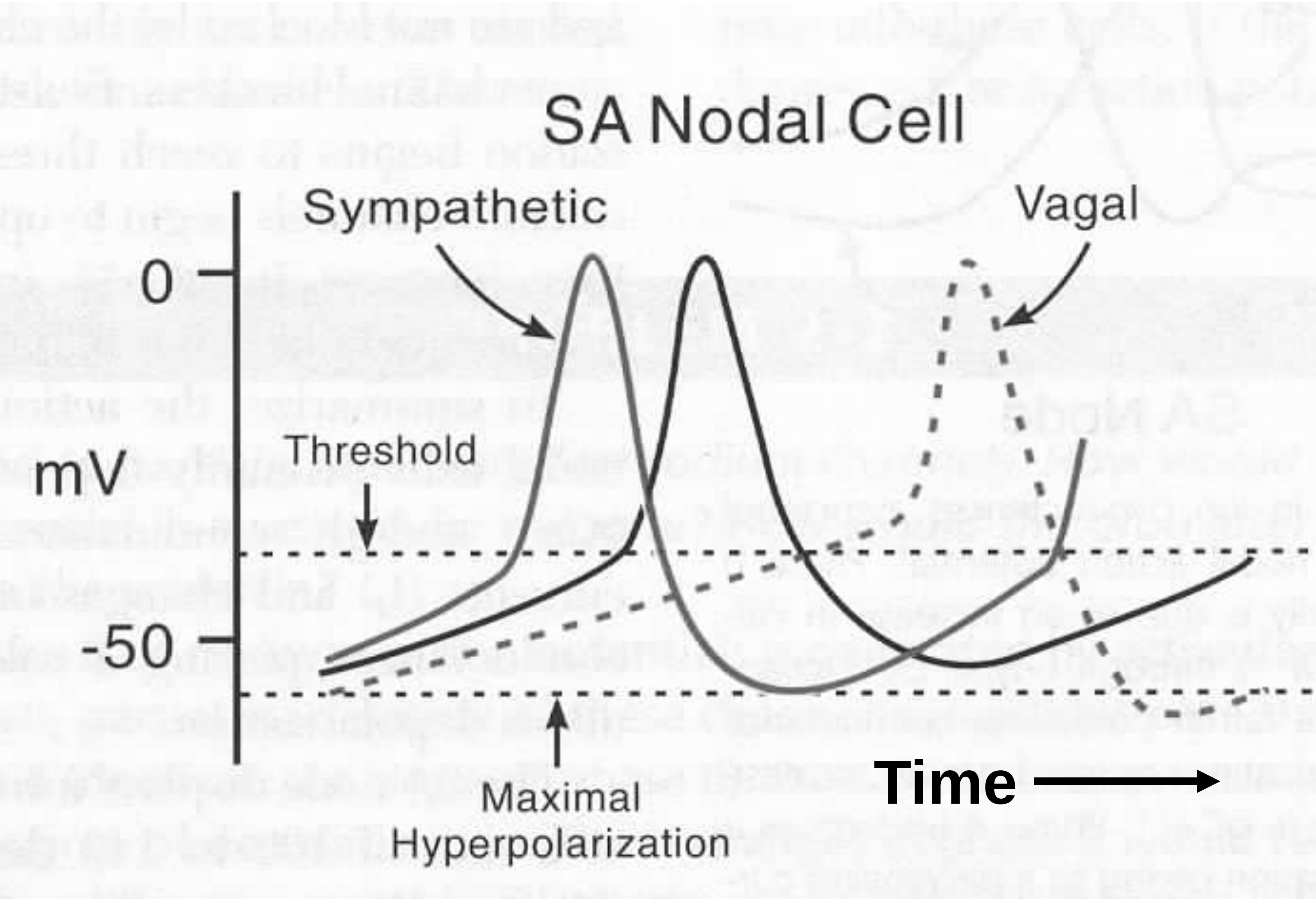
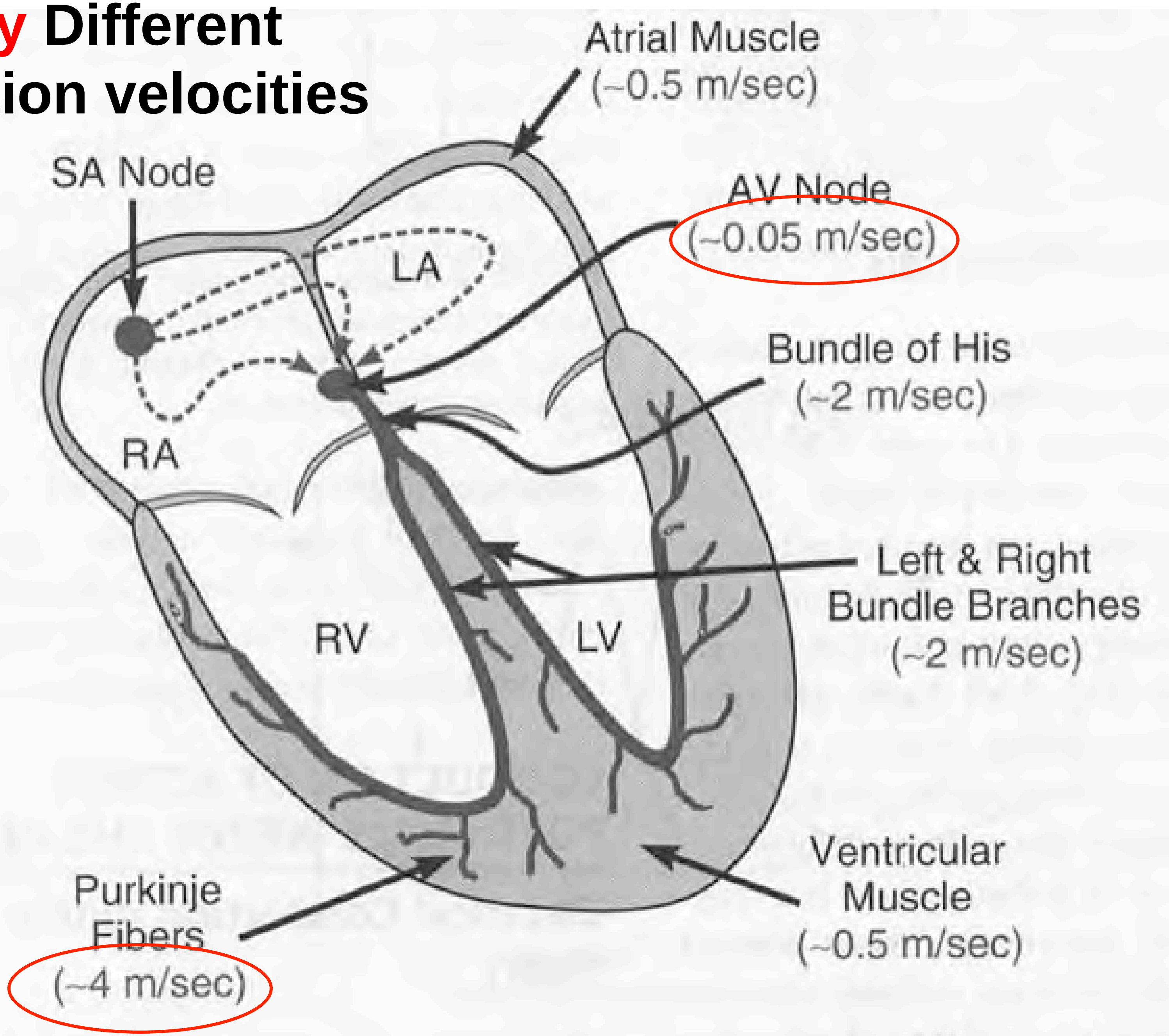
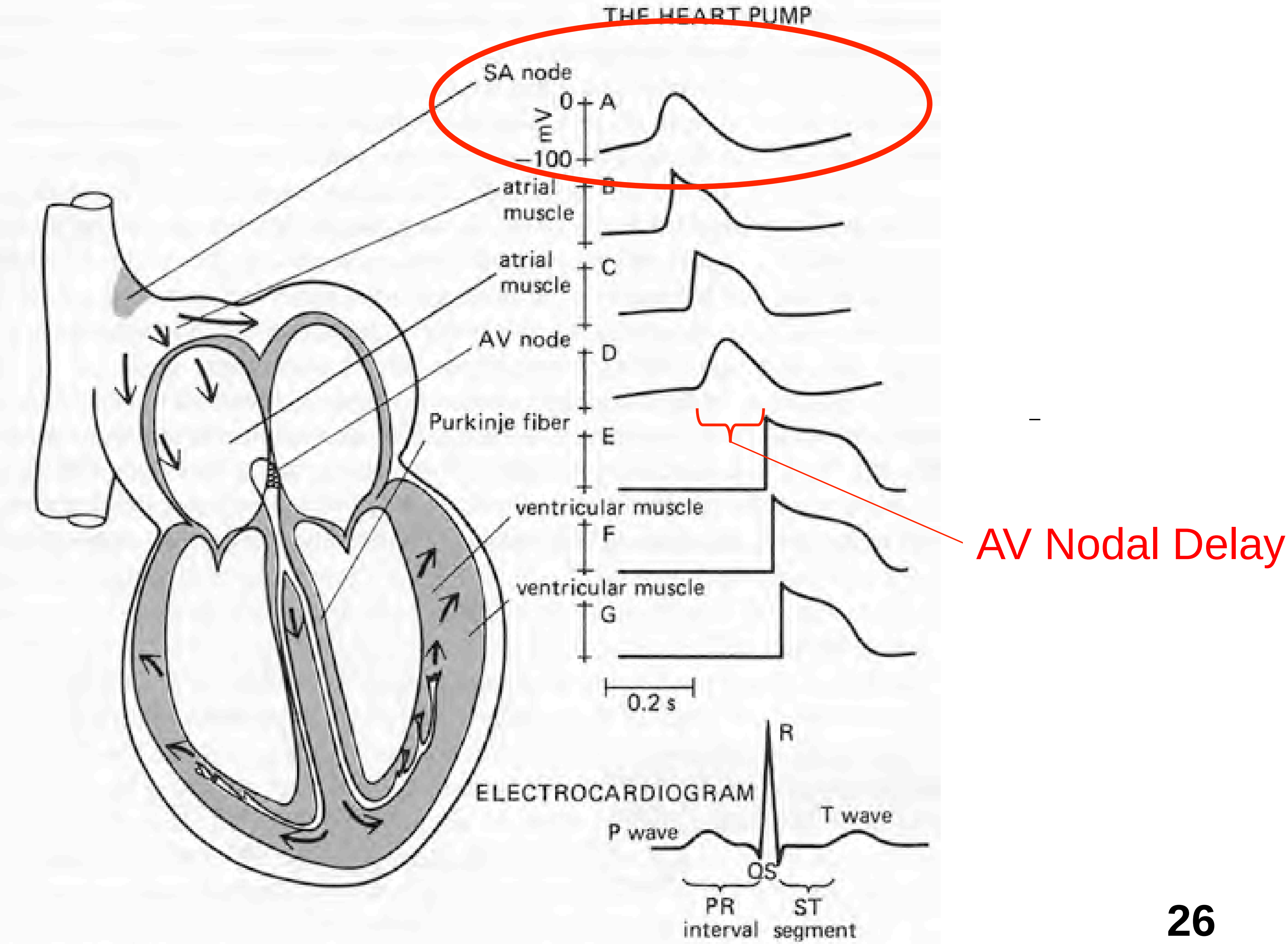


Fig. 1.15


SA Nodal Cell
Sympathetic
Vagal
0
mV
-50
Threshold
Maximal
Hyperpolarization
Time

Markedly Different conduction velocities





Source Undetermined

Normal Cardiac Cycle Outline 2

AFTER LUNCH

1) Stroke Volume
   - Preload
   - Afterload
   - Contractility
2) LV Pressure-Volume Loop
3) Measuring pressures CVP, RV,
   PAP, PCWP,LVEDP
4) Measuring Cardiac Output

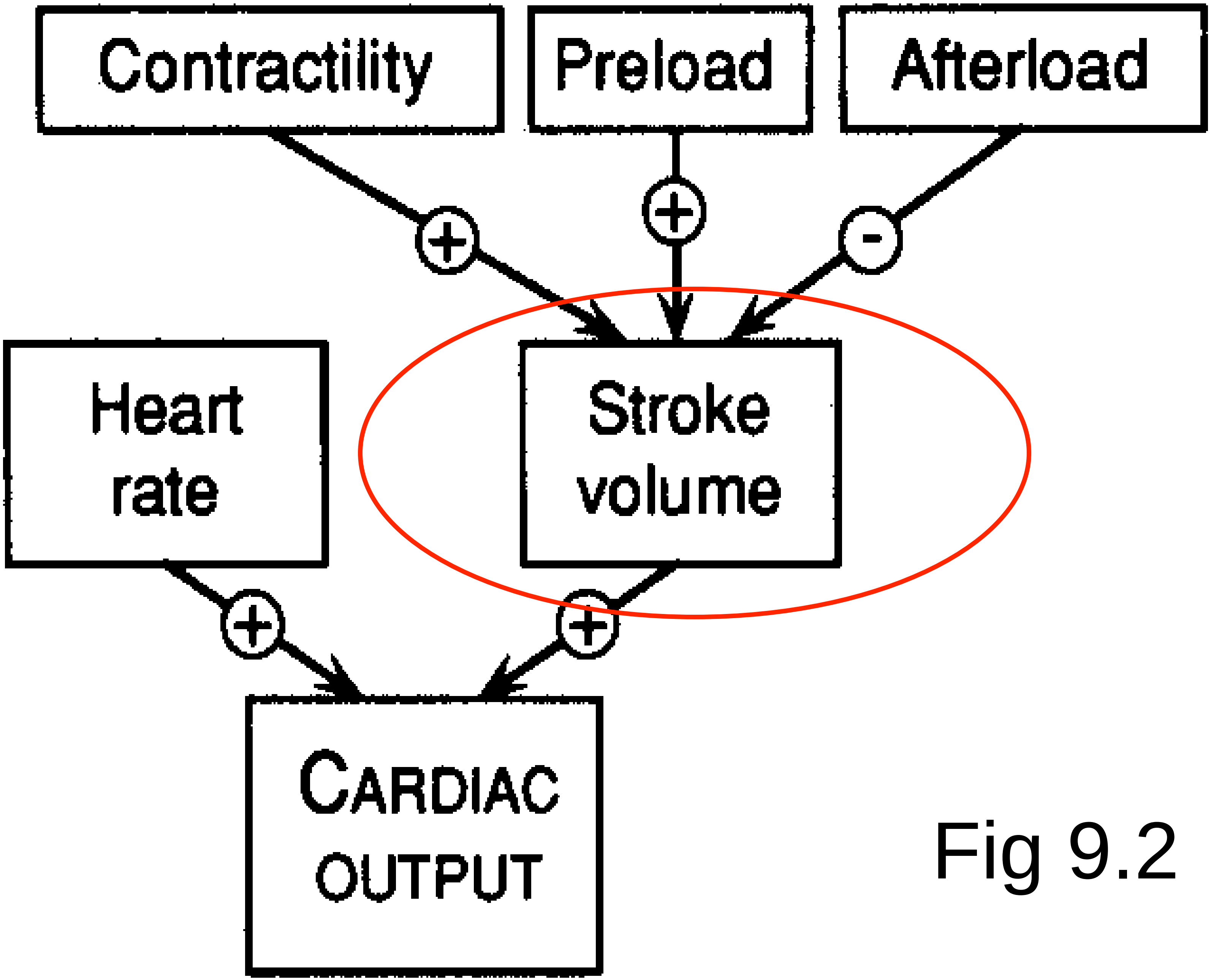

Contractility
Preload
Afterload
+
+
-
Heart rate
Stroke volume
+
+
CARDIAC OUTPUT

Fig 9.2

Lilly Table 9.1 Definitions

Preload - The ventricular wall tension at the end of diastole.

Afterload -- The ventricular wall tension during contraction; the resistance that must be overcome for the ventricle to eject its contents. Approximated by systolic ventricular or arterial pressure.

Contractility -- Property of heart muscle that accounts for changes in strength of contraction independent of preload and afterload.

Left ventricle pressure-volume loop

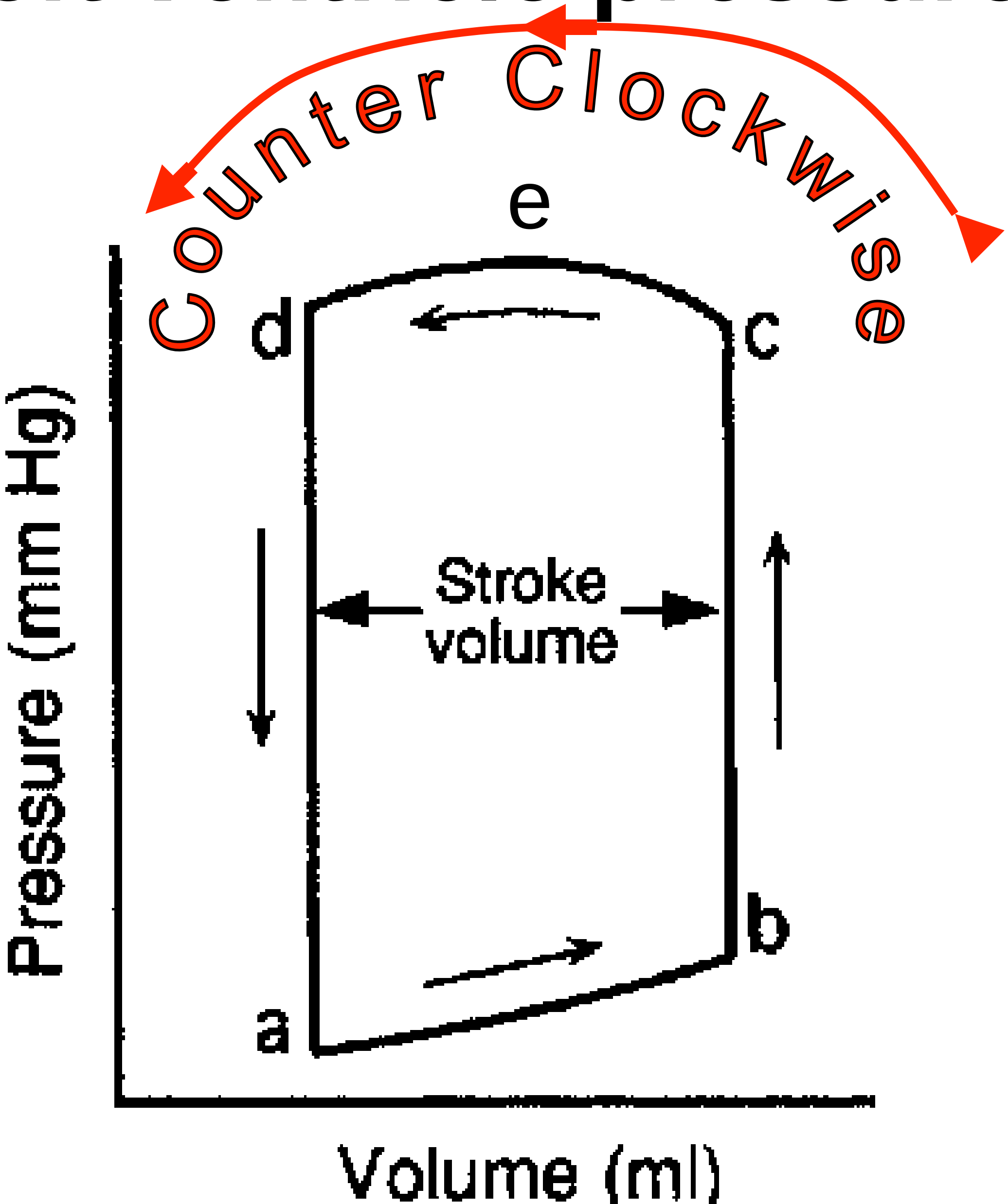
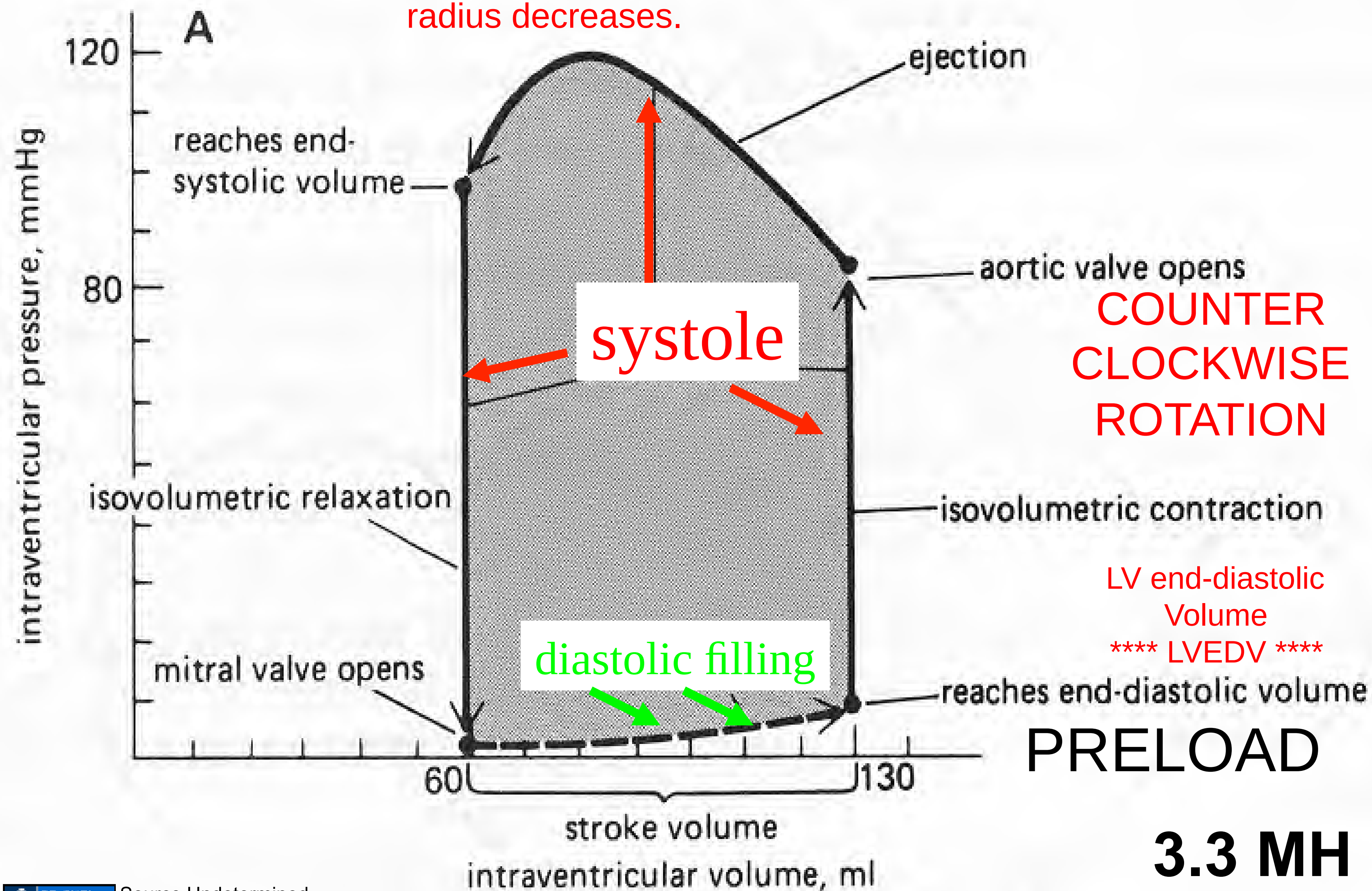


Fig. 9.4

Pressure increases as
radius decreases.



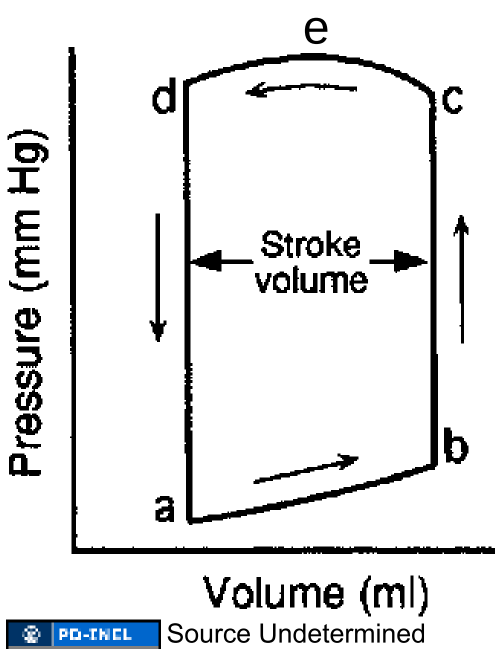
3.3 MH

Ejection Fraction = 70/130 = 54%

Matching Question
Know all the answers !!!!

- a
- a to b
- b
- c
- d
- e
- b to c
- c to d

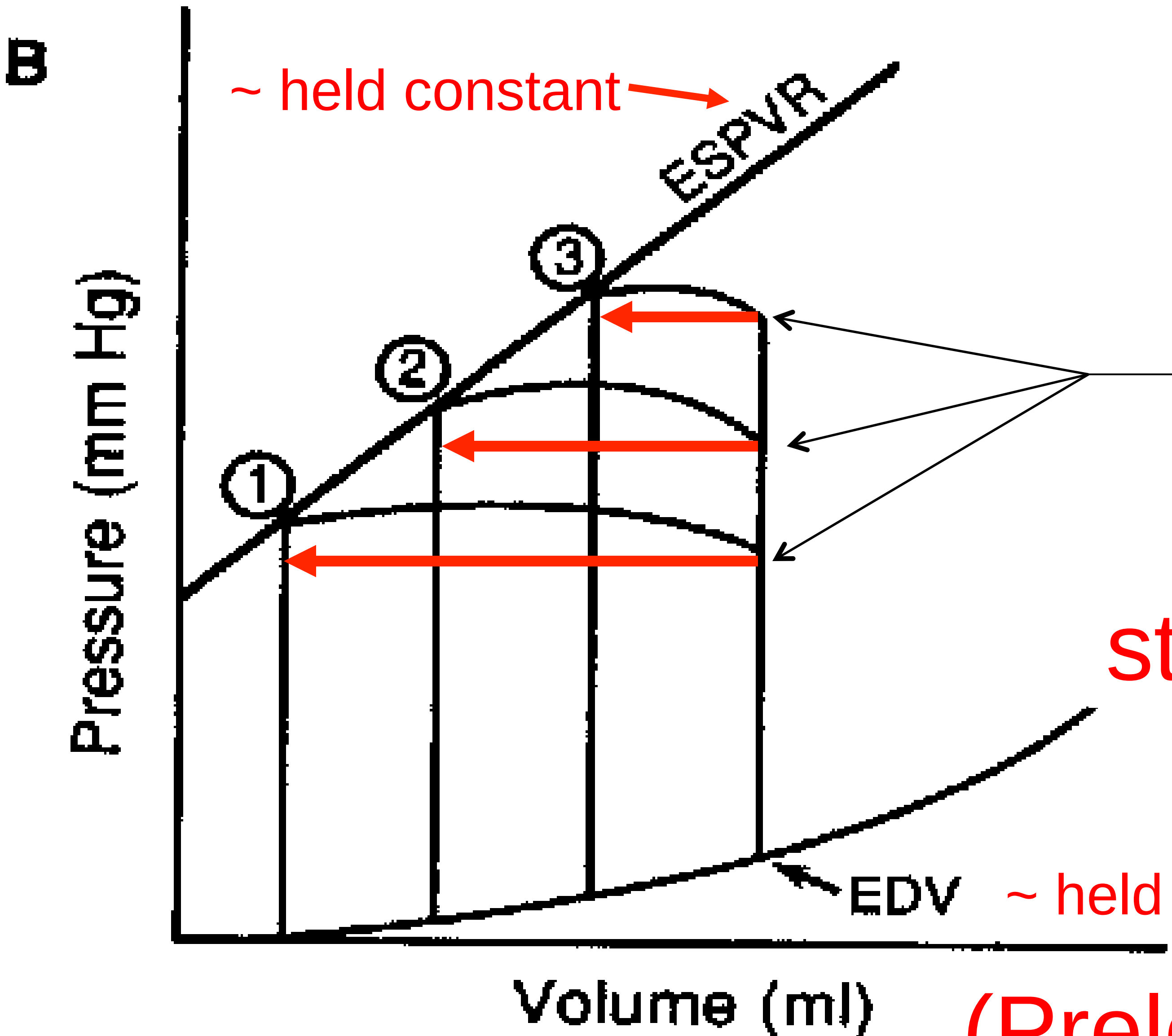
- Stroke volume
- Isovolumetric contraction
- Ventricular filling
- 1st heart sound
- 2nd heart sound
- Systolic arterial pressure
- Diastolic arterial pressure
- Left ventricular end-diastolic P&V
- Opening of atria-ventricular valve



LV Pressure-Volume Loop

- End-systolic pressure volume relationship (ESPVR).
- Slope of ESPVR ~ contractility
- Contractility ~ inotropic state
- Preload = stretch on ventricle @ end of diastole (~ EDP or EDV)
- Afterload = tension during contraction
  - (~ arterial pressure ~ MAP or diastolic AP)

****Major Figure **** Fig 9.5

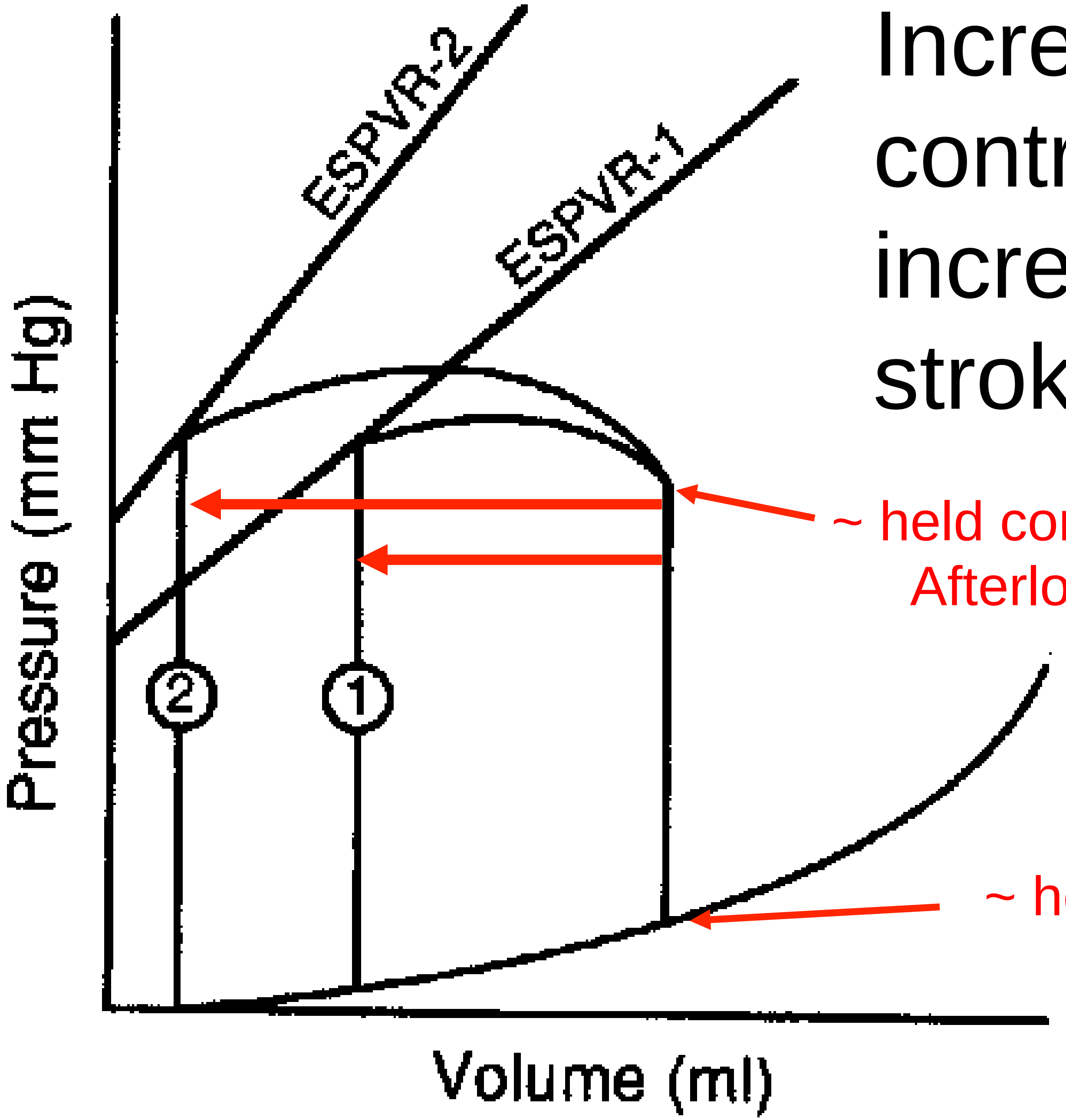


~ held constant

“Isolated” Increased afterload decreases stroke volume

(Preload)

C



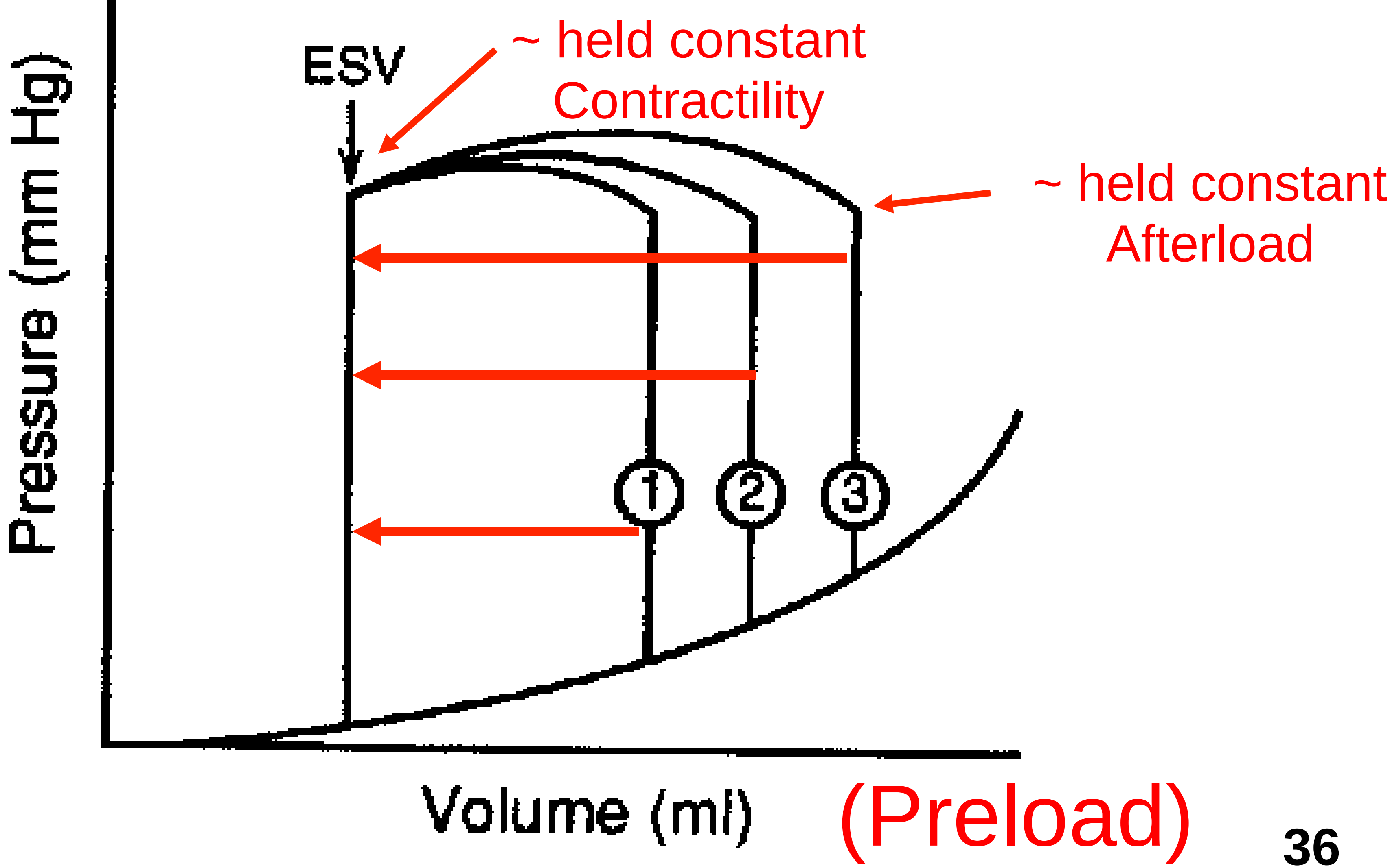
Increased contractility increases stroke volume

~ held constant Afterload

~ held constant Preload

A

Increased preload increases stroke volume



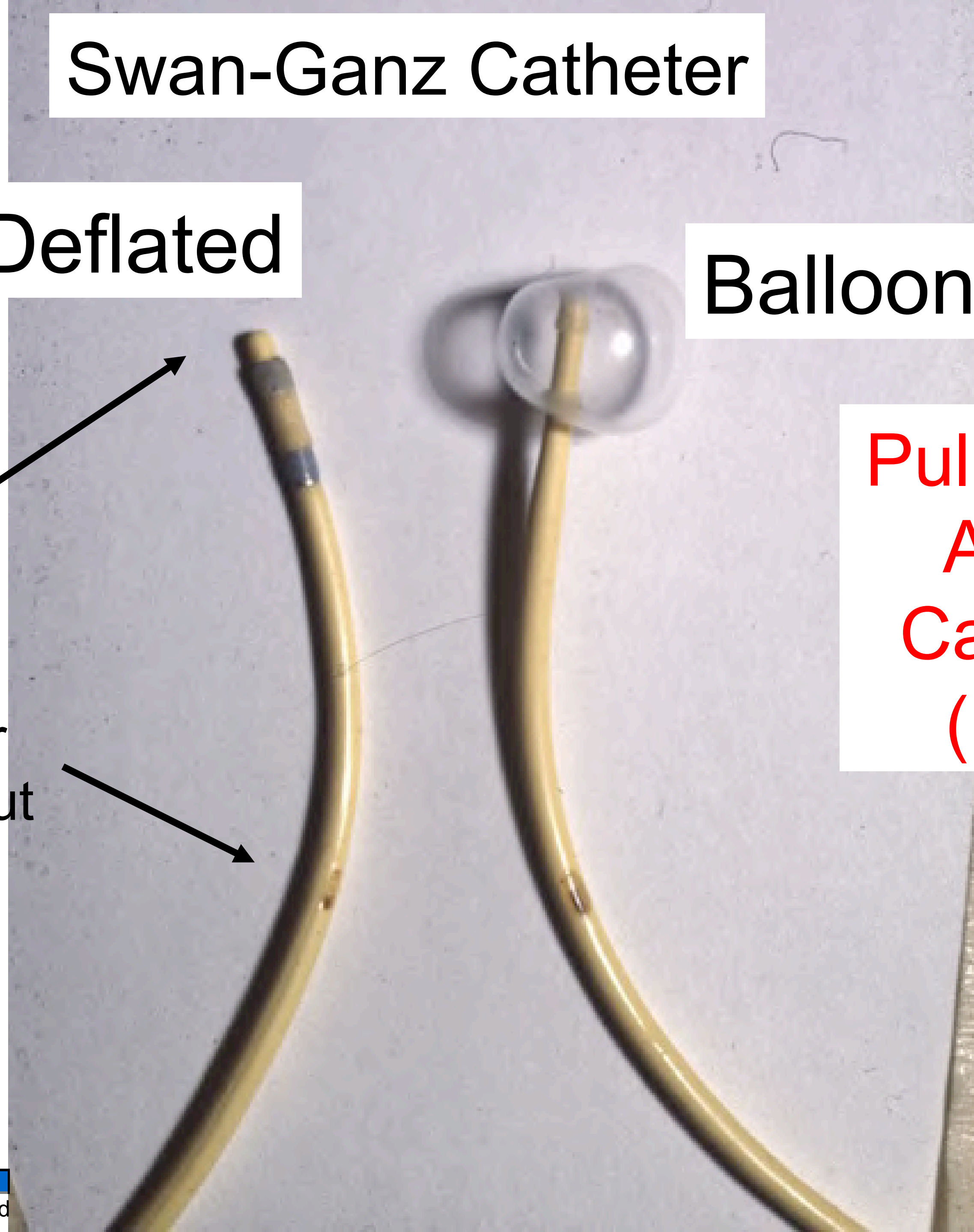
What should we be thinking about? Measuring?

- What are the differences in the interpretation of CVP and PCWP?
- What are the clinical concerns?
- What makes each go up and down? Physiologically and pathophysiologically?

CVP = central venous pressure

PCWP = pulmonary capillary wedge pressure

Swan-Ganz Catheter



Balloon Deflated

Balloon Inflated

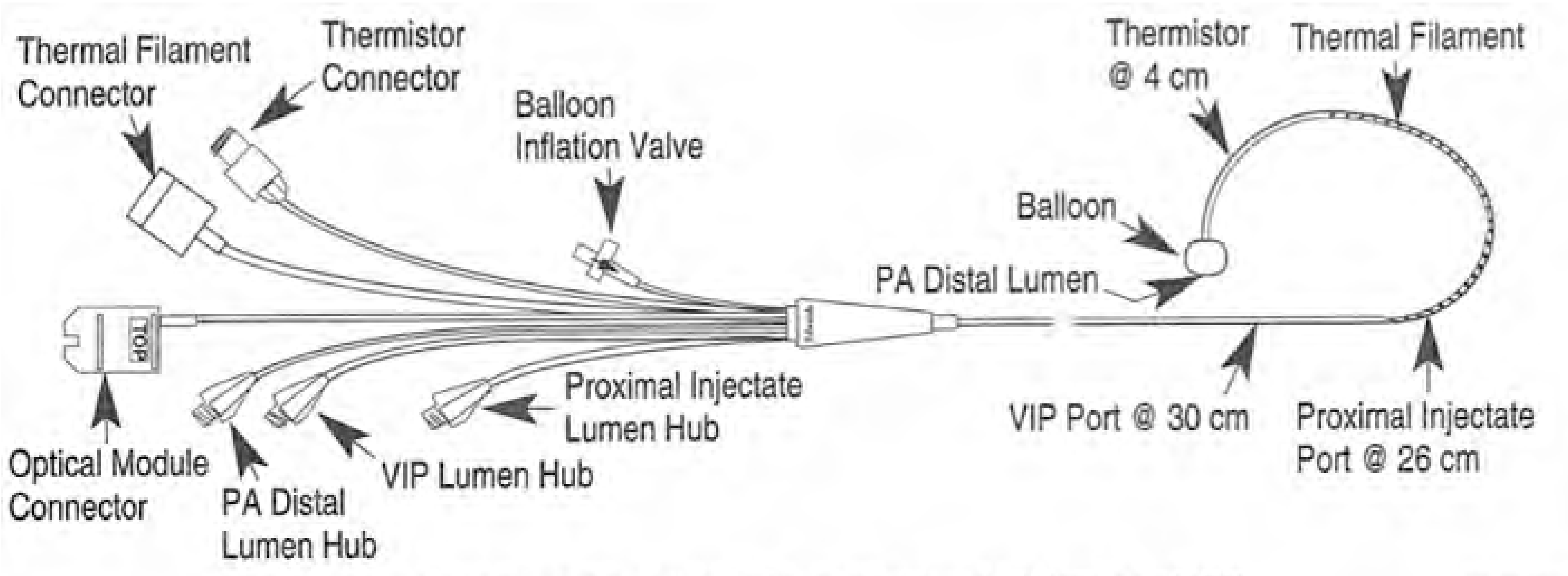
Distal Port for PCWP & PAP
RV -Sys, Dia
CVP

Thermistor for Cardiac Output

Pulmonary Artery Catheter (PAC)

Source Undetermined

Swan-Ganz Catheter



Swan-Ganz CCO/SvO_2/VIP TD Catheter (Model 746HF8 or 746F8) DC2133-2a

Edwards.com

Catheter X-Section

Insertion vein varies but: 50-60% Jugular, 30-40% Subclavian, 20-30% Arm or Leg

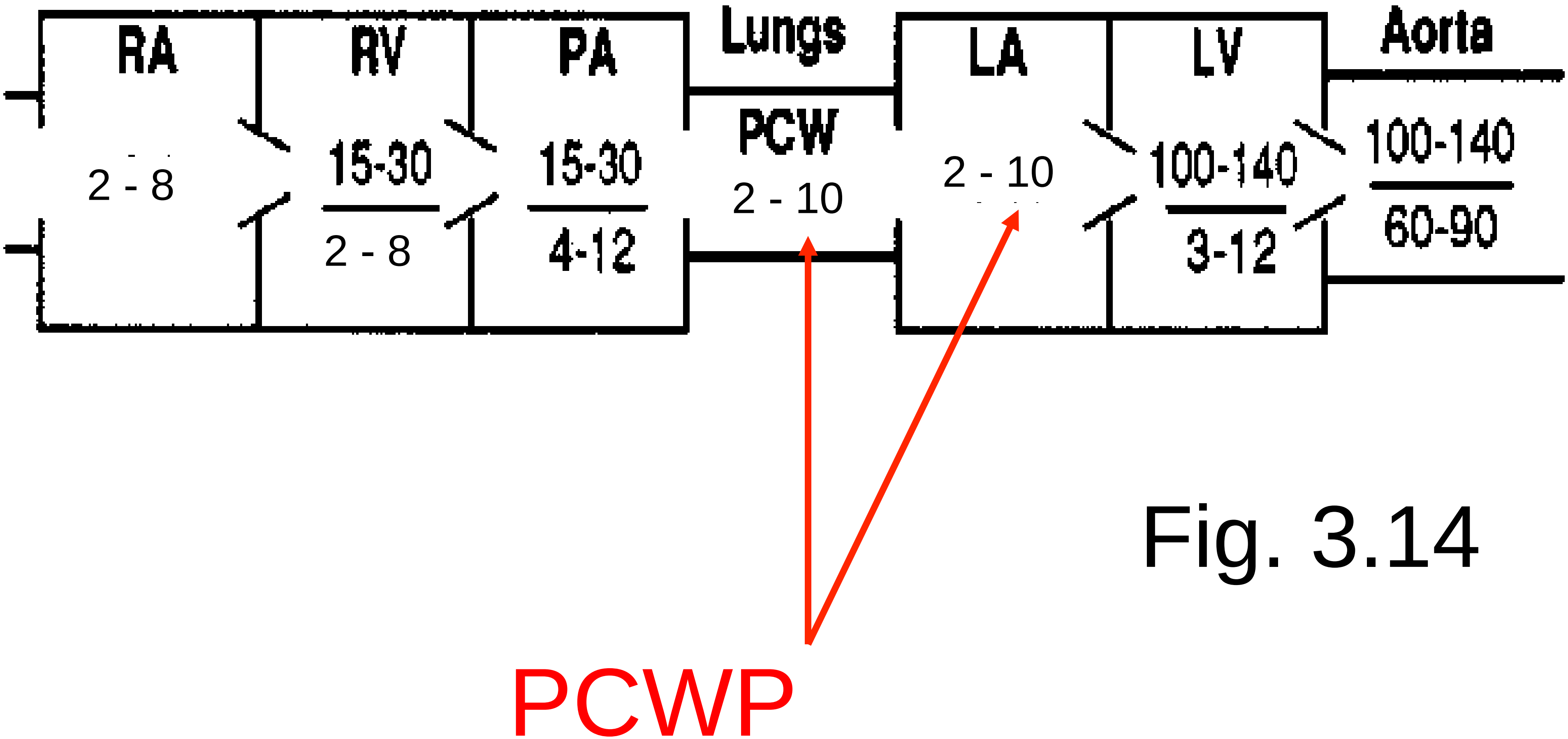
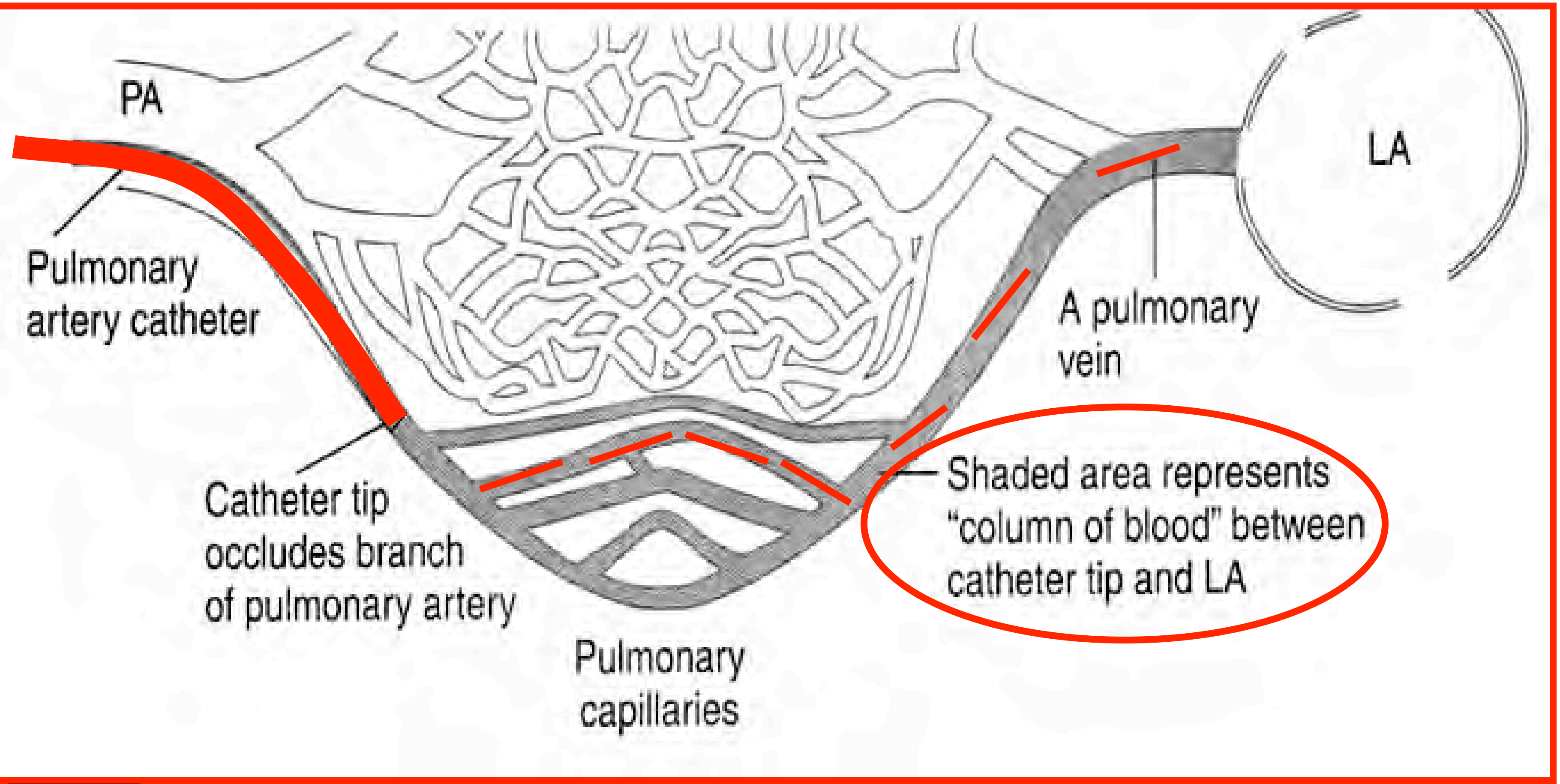


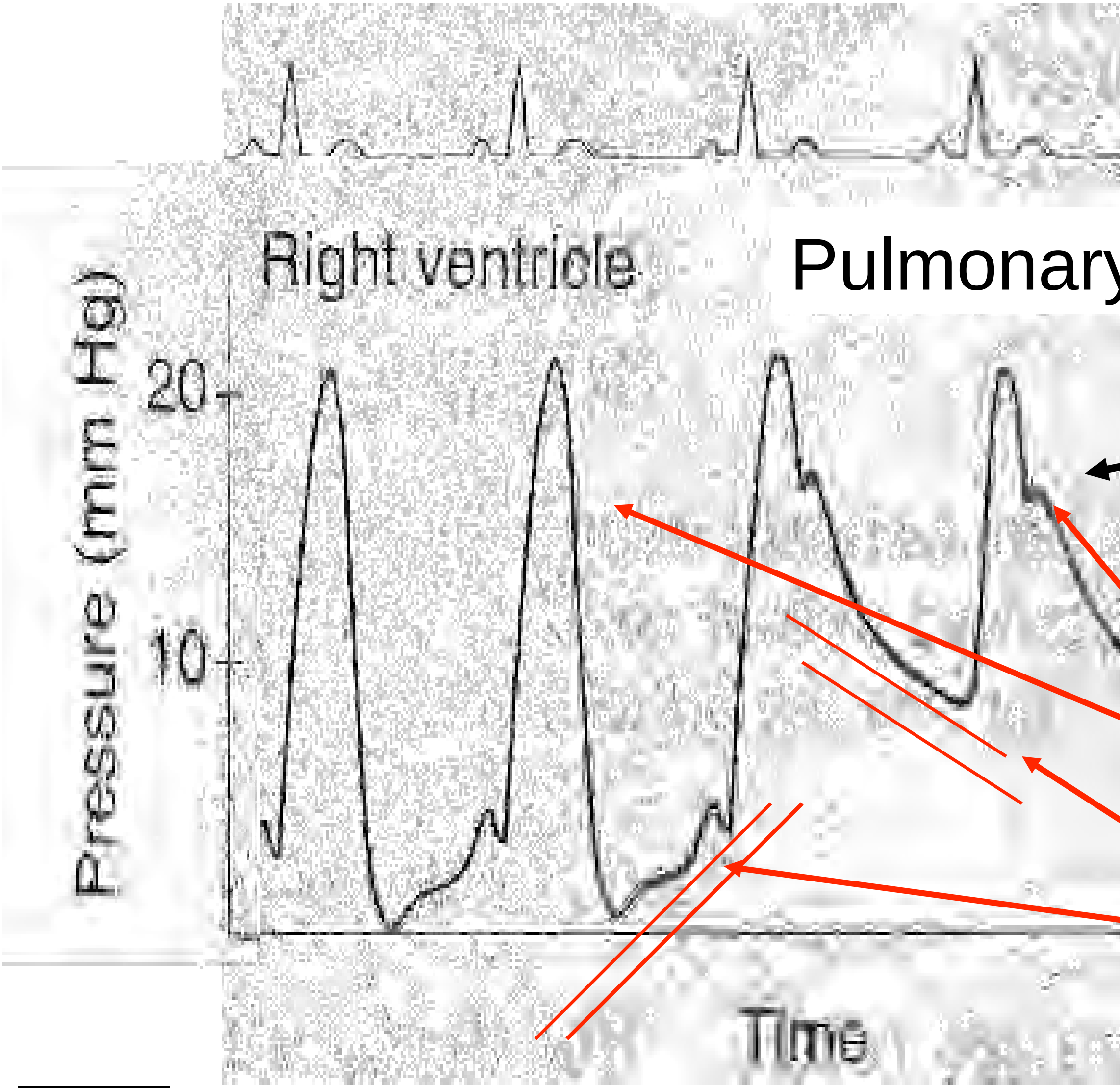
Fig. 3.14



PD-INEL Lilly Pg. 64, Fig. 3.15

Lilly Fig. 3.15
P 64

Pressure Changes as Catheter Moves Through Right Heart to PA to PCWP

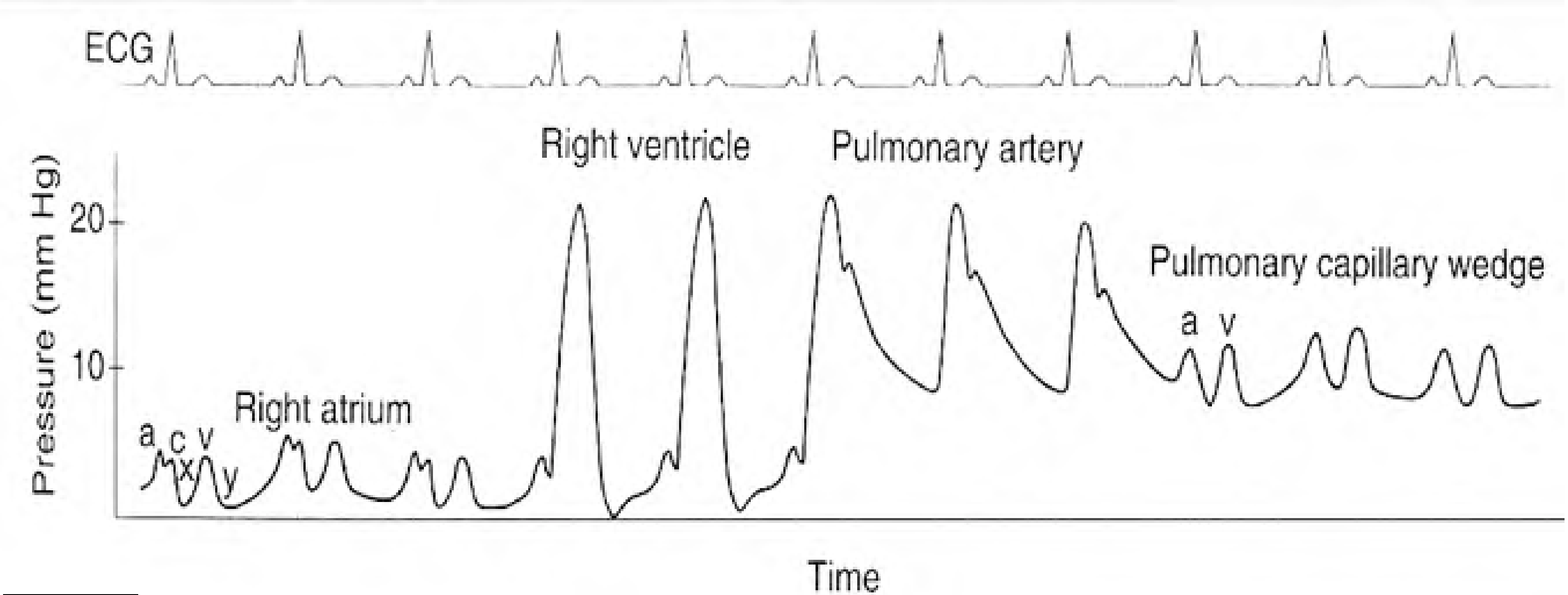


Pulmonary Artery

Dicrotic notch

PA vs. RV
- 1) has notch
- 2) > diastole
- 3) dn vs.. up

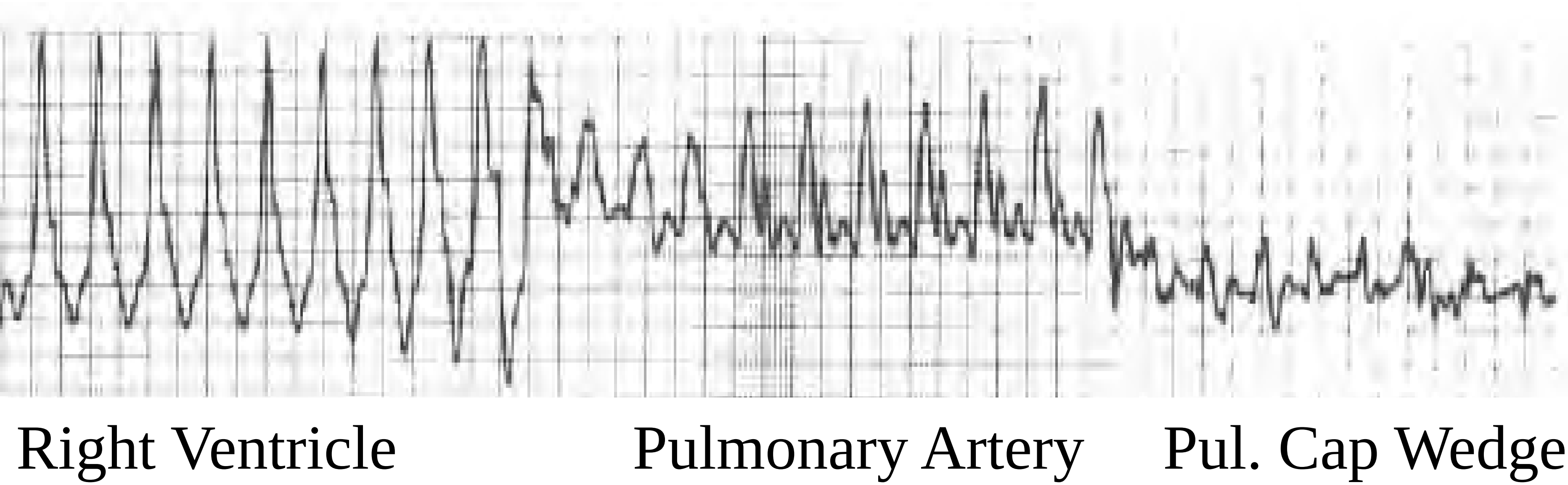
Box 3.1

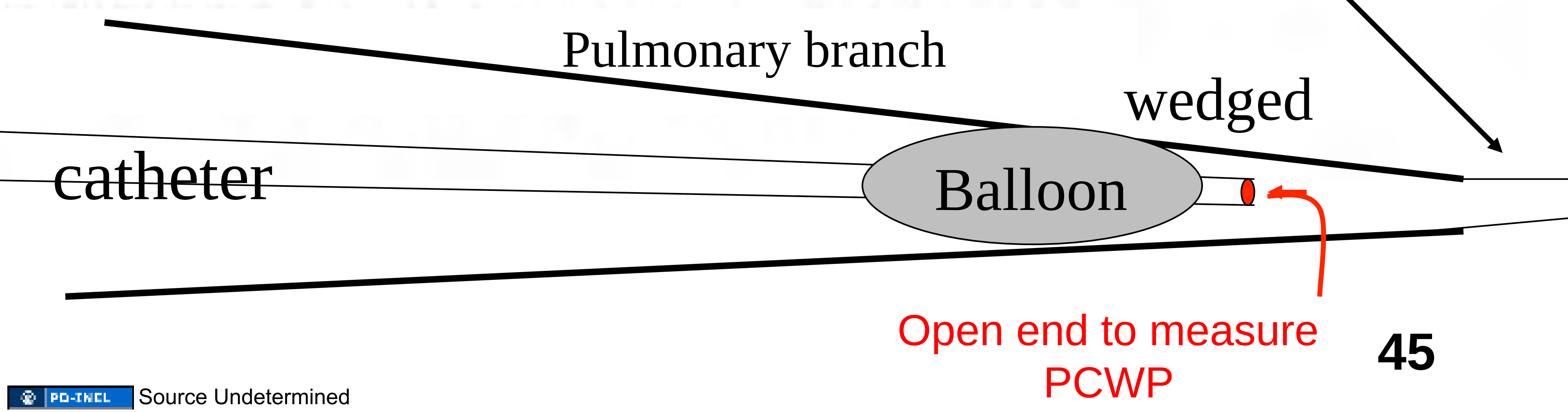


Pressure Changes as Catheter Moves

Through Right Heart to PA & PCWP

Swan-Ganz Catheter Pressure Recording





LV EDV

LV EDP (Preload)

LAP

Pulmonary Venous P

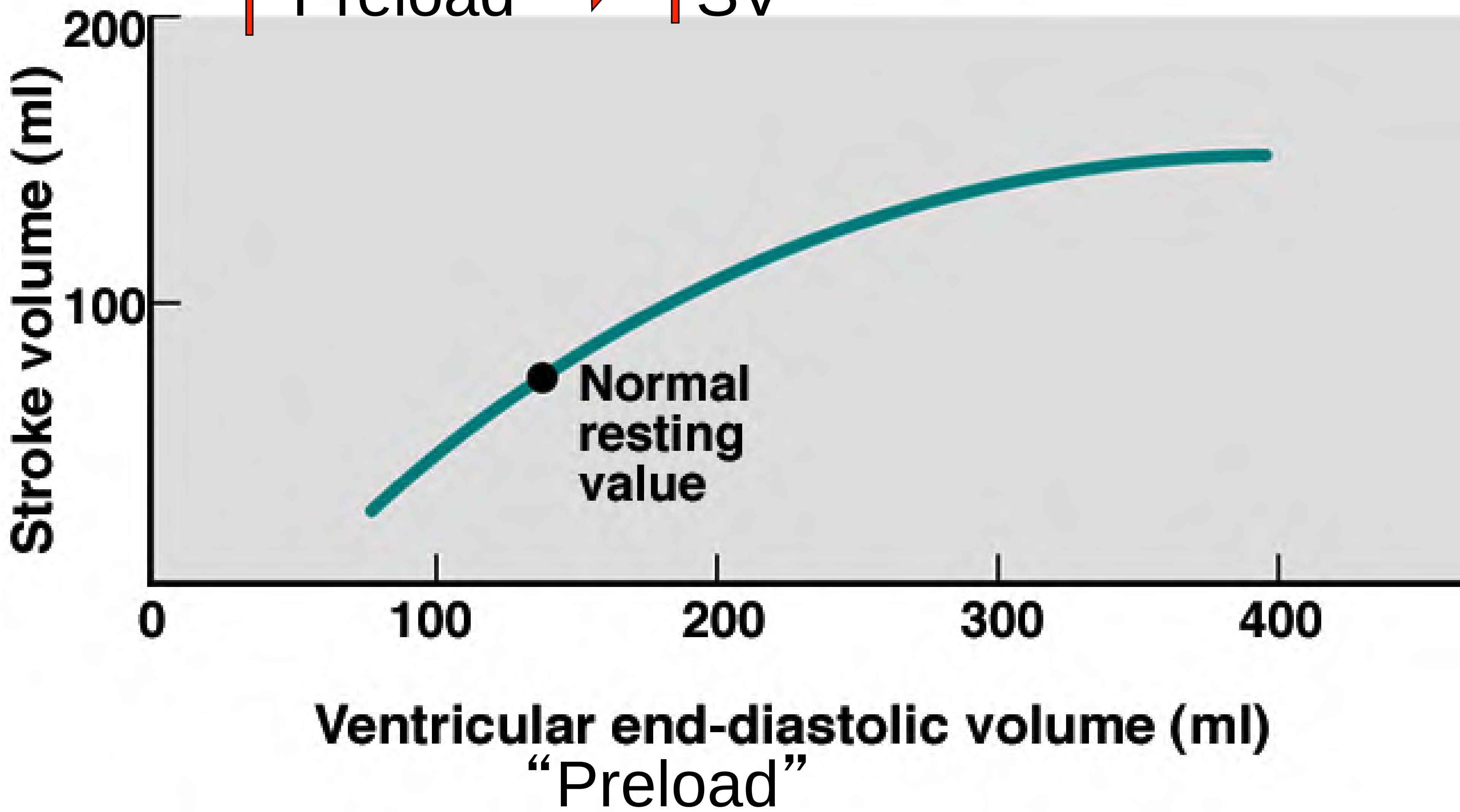
Pul Cap P

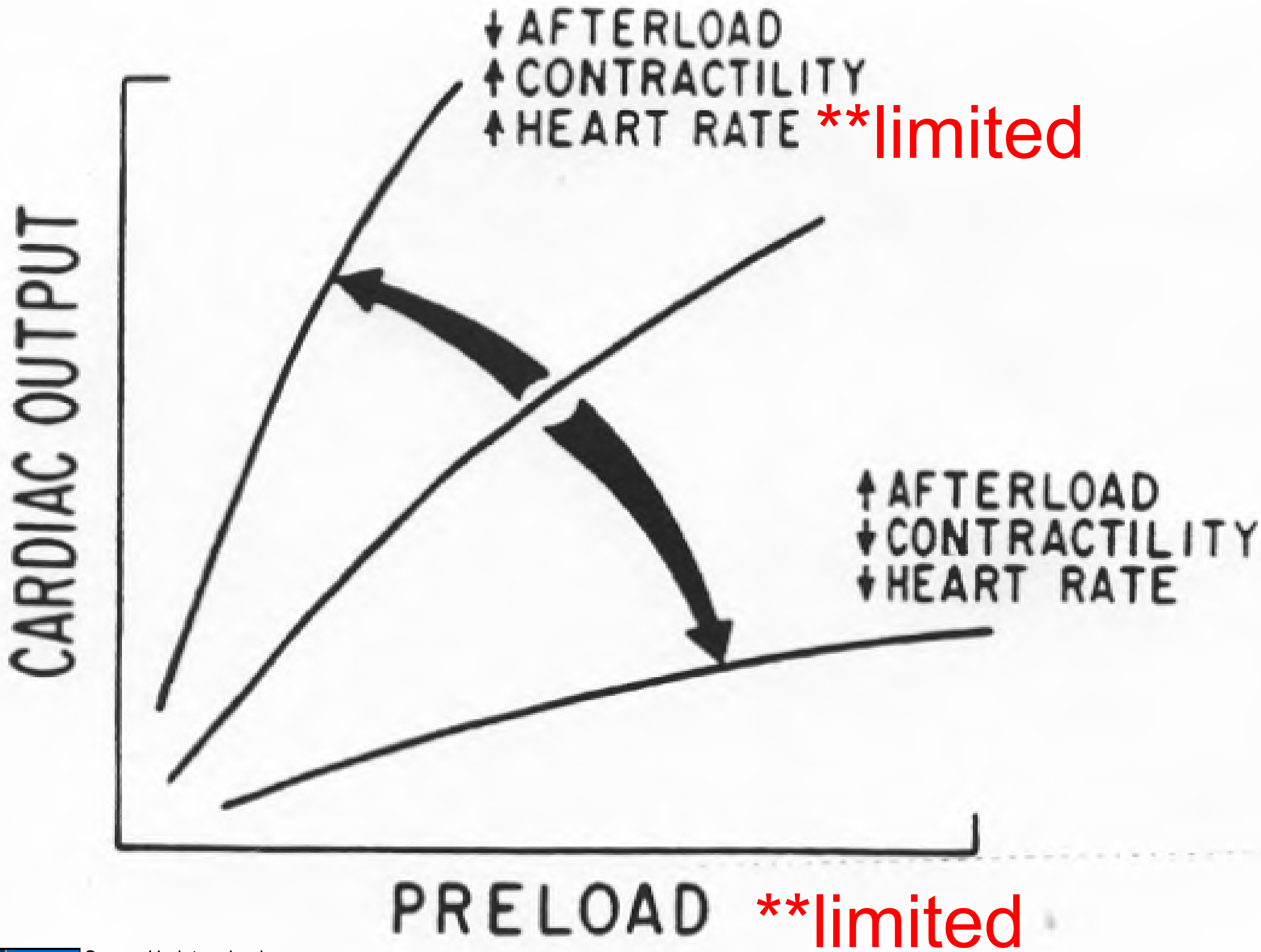
Pulmonary Capillary
Wedge Pressure

PCWP is used as an index of LV EDP PRELOAD

Ventricular function curve

↑ Preload → ↑SV





↓ AFTERLOAD
↑ CONTRACTILITY
↑ HEART RATE
**limited
CARDIAC OUTPUT
↑ AFTERLOAD
↓ CONTRACTILITY
↓ HEART RATE
PRELOAD
**limited

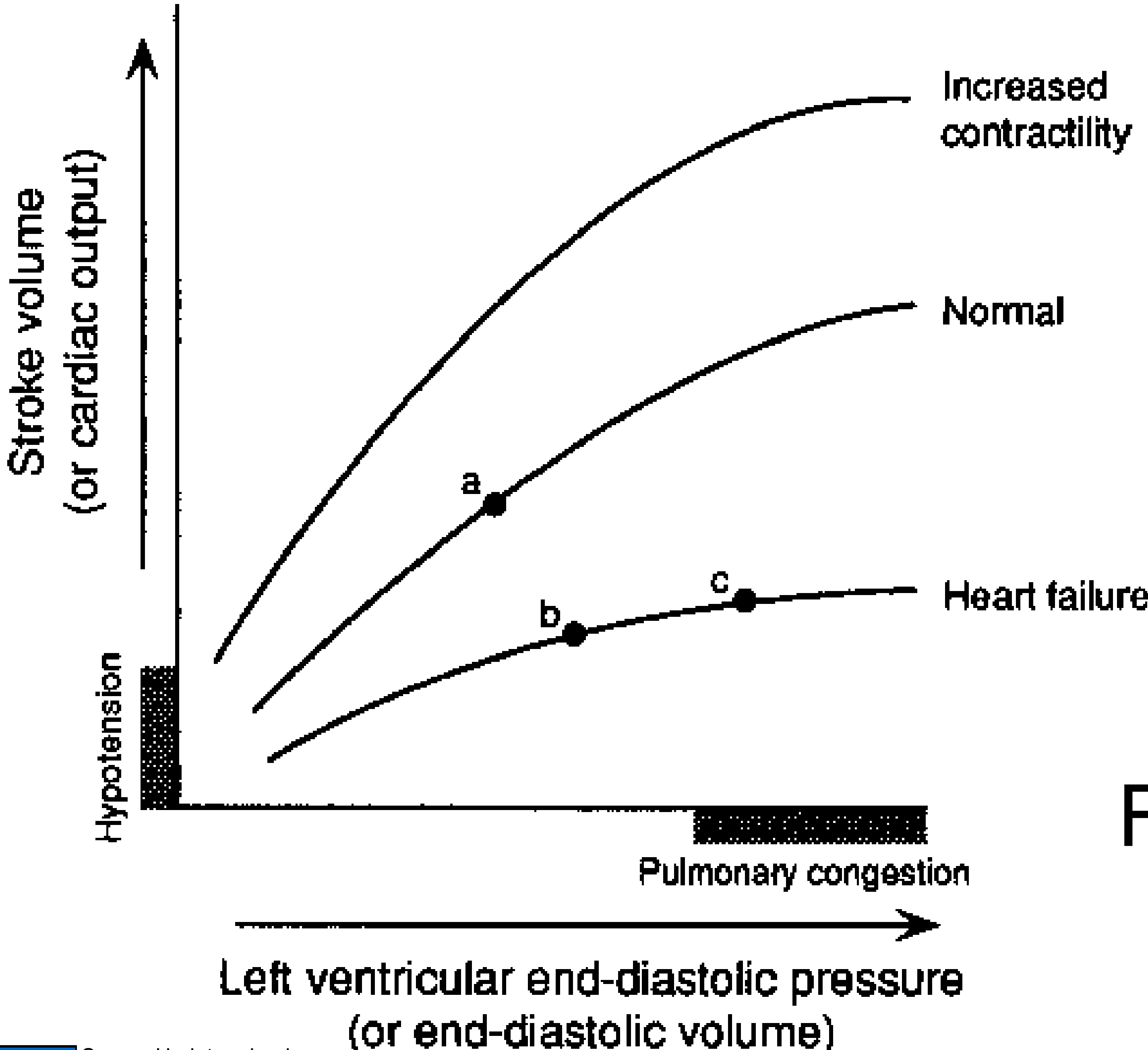
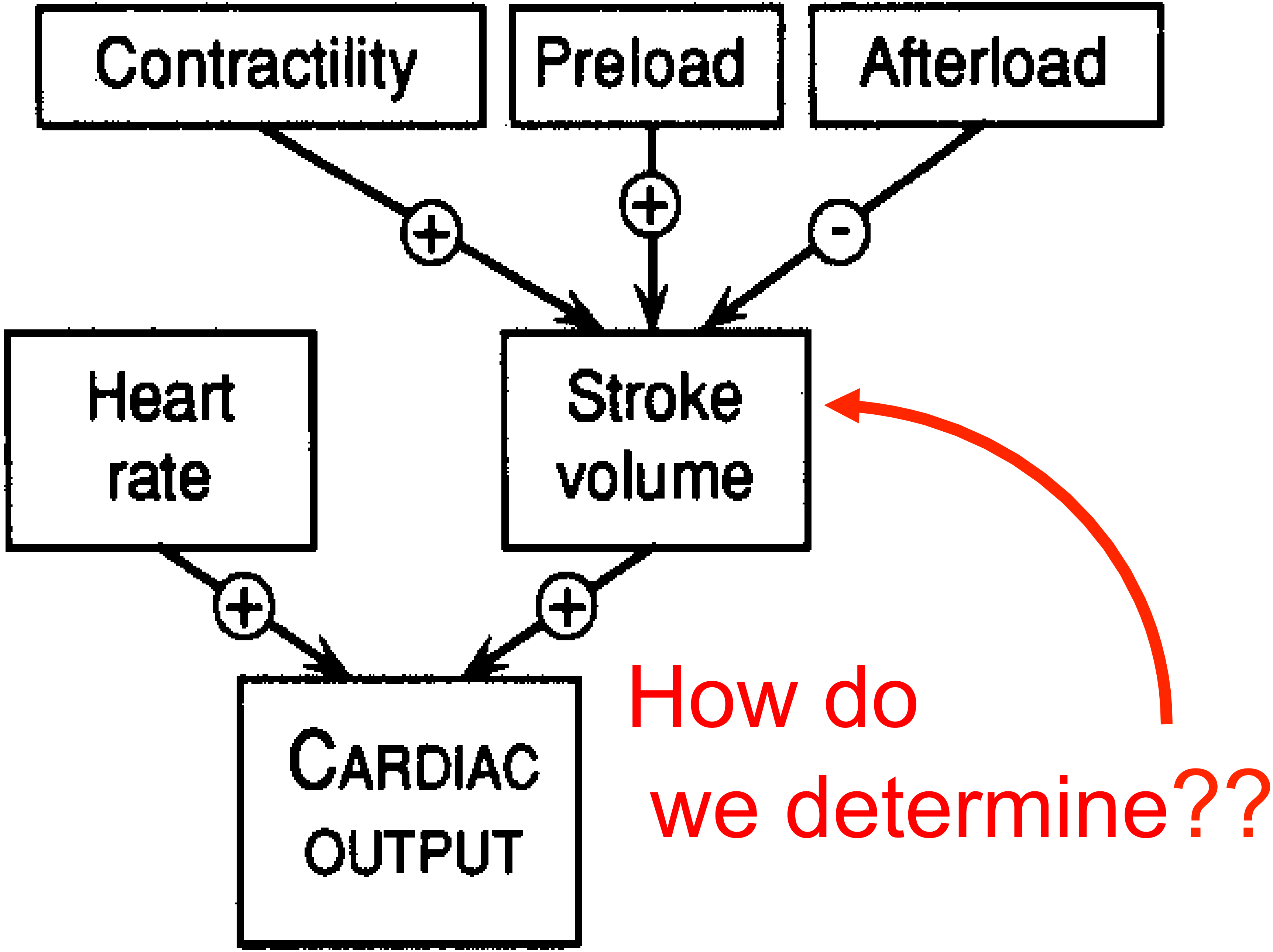

Stroke volume
(or cardiac output)
Increased
contractility
Normal
a
c
b
Heart failure
Hypotension
Pulmonary congestion
Left ventricular end-diastolic pressure
(or end-diastolic volume)

Fig. 9.3


Contractility
Preload
Afterload
+
+
-
Heart rate
Stroke volume
+
+
CARDIAC OUTPUT
How do we determine??

Heart is a Pressure Pump but also pumps volume/time

Heart Rate X Stroke volume = Cardiac Output

Measure

Cardiac Output by Thermal Dilution

Calculate SV

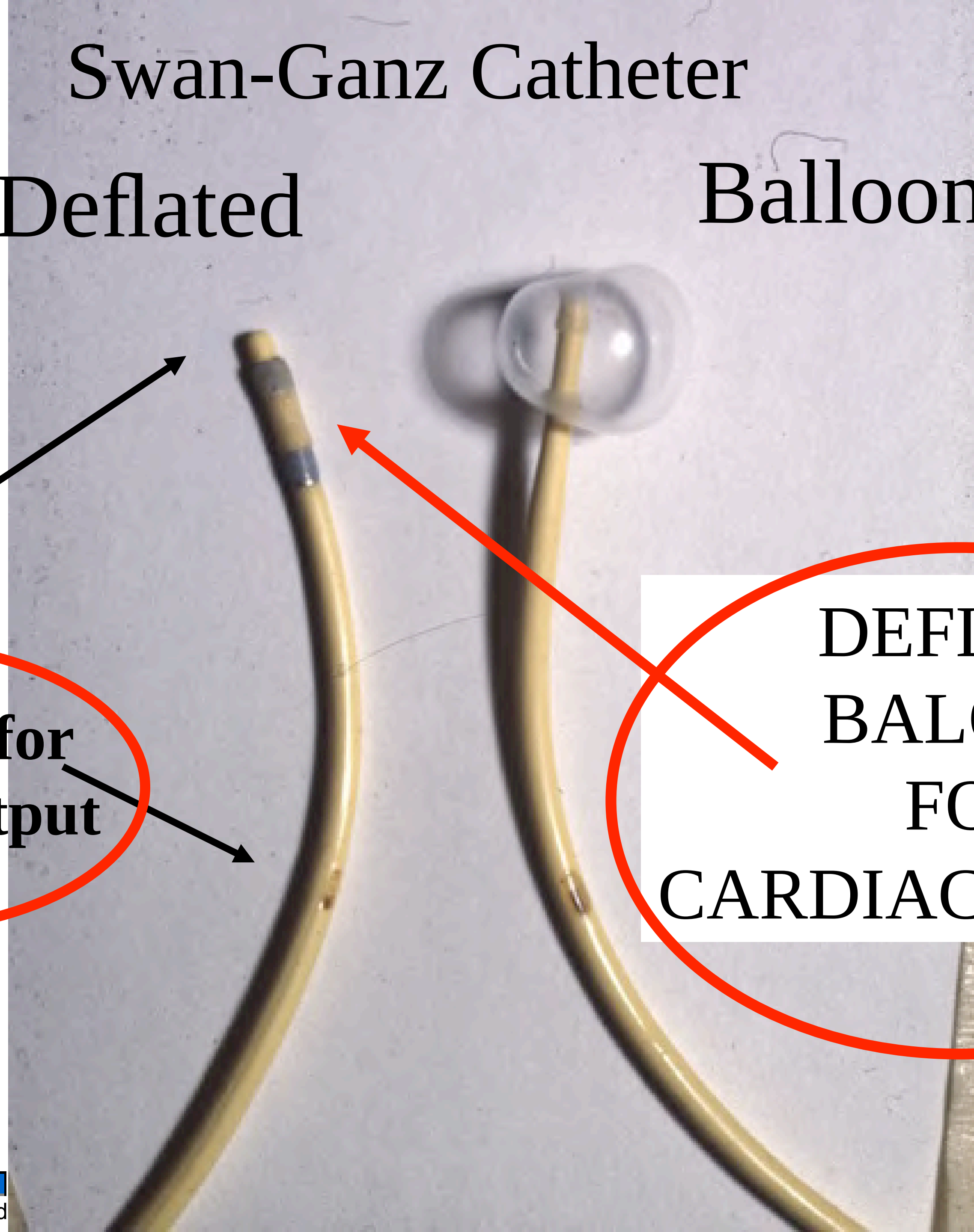
HR X SV = CO

b /min X mL /b = mL /min

Swan-Ganz Catheter

Balloon Deflated

Balloon Inflated



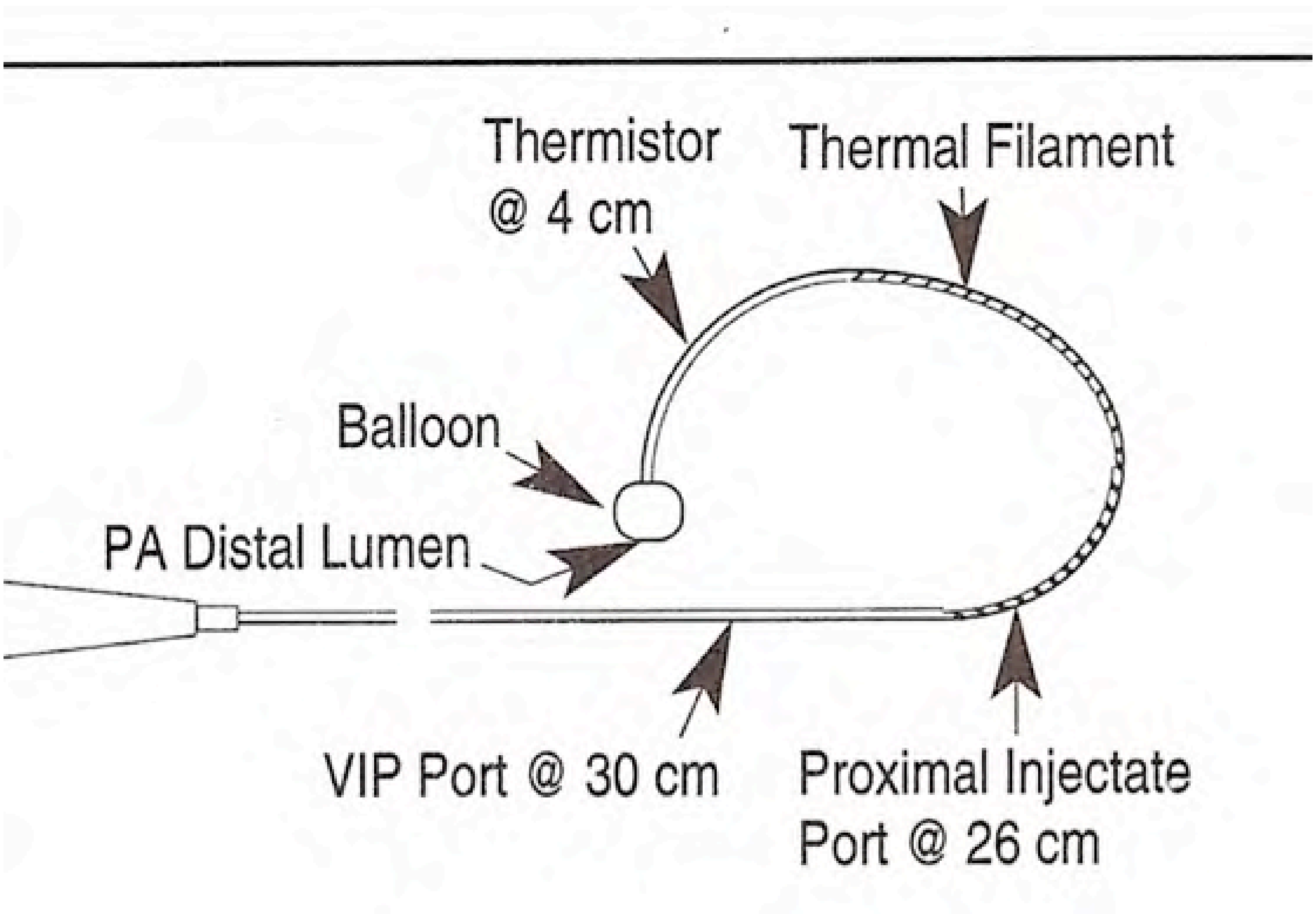
Distal Port for PCWP

Thermistor for Cardiac Output

DEFLATE BALOON FOR CARDIAC OUTPUT

PD-INEL
Source Undetermined

CO by Swan - Ganz



The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MAY 25, 2006 VOL. 354 NO. 21

Pulmonary-Artery versus Central Venous Catheter to Guide Treatment of Acute Lung Injury

The National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Clinical Trials Network*

Conclusions: PAC-guided therapy did not improve survival or organ function but was associated with more complications than CVC-guided therapy. These results, when considered with those of previous studies, suggest that the PAC should not be routinely used for the management if acute lung injury.

(Clinical Trials.gov num, NCT00281268.)

PAC

Pulmonary artery catheter use is associated with reduced mortality in severely injured patients: A National Trauma Data Bank analysis of 53,312 patients*

Randall S. Friese, MD; Shahid Shafi, MD; Larry M. Gentilello, MD

Conclusions: Trauma patients managed with a PAC are more severely injured and have a higher mortality. However, severely injured patients (Injury Severity Score, 25–75) who arrive in severe shock, and older patients, have an associated survival benefit when managed with a PAC. This is the first study to demonstrate a benefit of PAC use in trauma patients. (Crit Care Med 2006; 34:1597–1601)

Severity of illness and risk of death associated with pulmonary artery catheter use*

by

Dean R. Chittock et al

Crit Care Med 2004 Vol. 32, No.4

PDF on web site

thanks for your interest,
i have no problem with you using it as a PDF on the web page..attached is the PDF...in answer to the safety...there are two large trials ongoing ....one in the US from NIH and the other in UK...they should answer the outstanding questions for us...ps... there is nothing inherently wrong with the catheter...just with the users!

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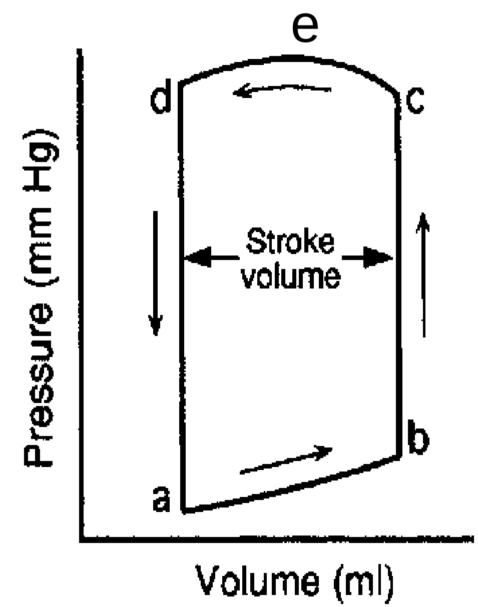
(Clinical Trials.gov num, NCT00281268.)

Cardiovascular System Central Pressures (mmHg)		
	RANGE	TYPICAL
1 Right Atrium	-1 to +7	+3
2 Rt. Ventricle		
Systolic	15 to 30	24
Diastolic	0 to 8	4
3 Pulmonary Artery (PAP)		
Systolic	15 to 30	24
Diastolic	8 to 15	9
Mean	10 to 20	15
4 Pulmonary Capillary Wedge Pressure	8 to 12	10
5 Left Ventricle		
Systolic	90 to 140	130
Diastolic	5 to 12	9
6 Aorta (Systemic Art.)		
Systolic	90 to 140	125
Diastolic	60 to 90	70
Mean	70 to 108	90

Matching Question
Know all the answers !!!!

- a
- a to b
- b
- c
- d
- e
- b to c
- c to d

- Stroke volume
- Isovolumetric contraction
- Ventricular filling
- 1st heart sound
- 2nd heart sound
- Systolic arterial pressure
- Diastolic arterial pressure
- Left ventricular end-diastolic P&V
- Opening of atria ventricular valve



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Slide 14: Source Undetermined
Slide 15: Source Undetermined
Slide 16: Source Undetermined
Slide 17: Source Undetermined
Slide 22: McGraw-Hill
Slide 23: Source Undetermined
Slide 24: Source Undetermined
Slide 25: Source Undetermined
Slide 26: Source Undetermined
Slide 27: Source Undetermined
Slide 28: Source Undetermined
Slide 29: Lilly
Slide 30: Source Undetermined
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Slide 36: Source Undetermined
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Slide 38: Source Undetermined
Slide 39: Source Undetermined; Source Undetermined
Slide 40: Source Undetermined
Slide 41: Lilly Pg. 64, Fig. 3.15
Slide 42: Source Undetermined
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Slide 45: Source Undetermined
Slide 47: McGraw-Hill
Slide 48: Source Undetermined
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Slide 50: Source Undetermined
Slide 52: Source Undetermined
Slide 53: Source Undetermined
Slide 54: New England Journal of Medicine
Slide 55: Source Undetermined
Slide 58: New England Journal of Medicine
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