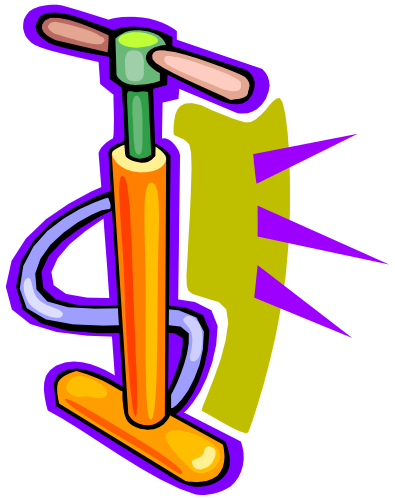
The “Thoracic Pump” Impetus for the Respiratory Arterial Pressure Wave and Breathing Induced Heart Rate Variability

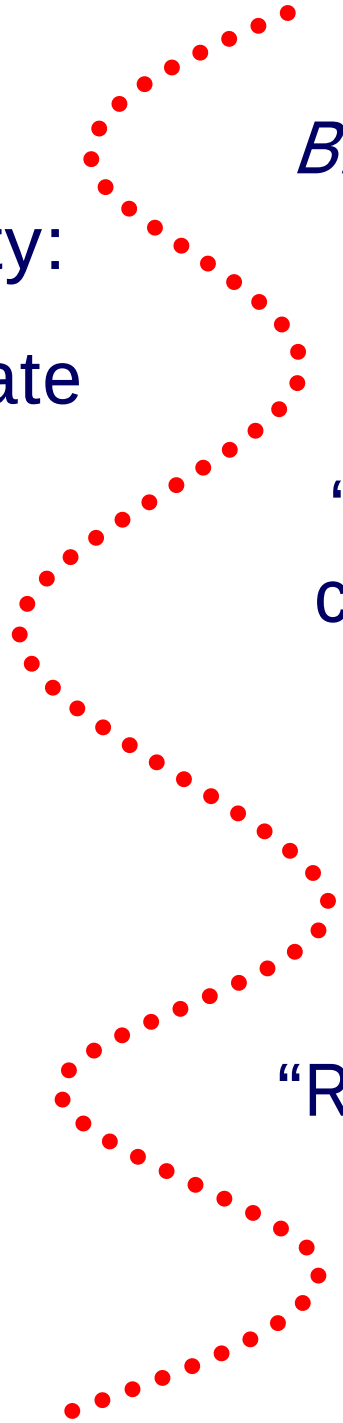


Stephen Elliott – President & Life Scientist, COHERENCE

The Thoracic Pump

Heart Rate Variability:

"Variation in heart rate for any reason."



Breathing Induced Heart Rate Variability:

"Variation in heart rate as a consequence of respiration."

We also know this as "Respiratory Sinus Arrhythmia" or "RSA".

Respiratory Sinus Arrhythmia

The phenomenon of RSA:

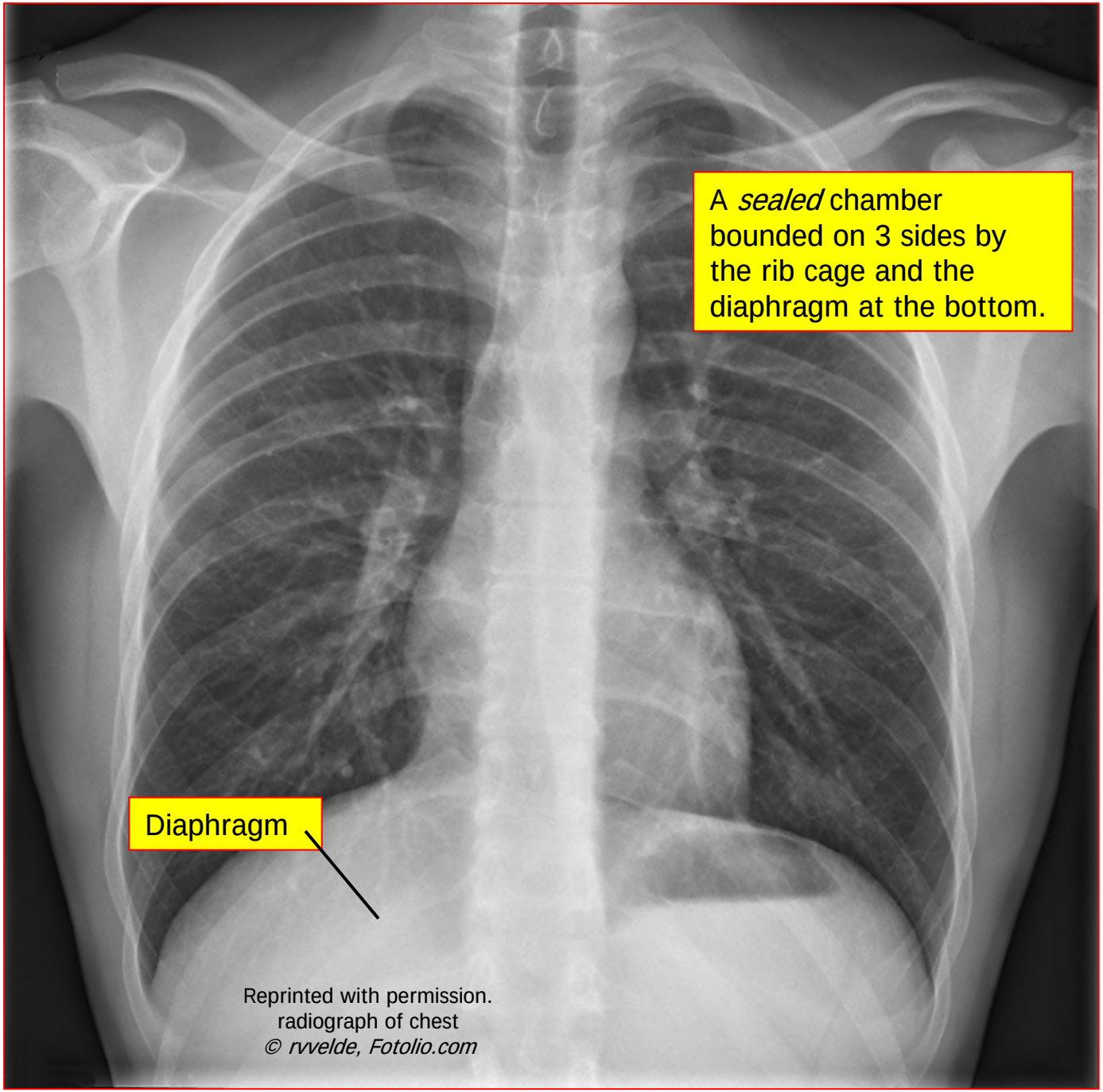
“Heart rate tends to increase with inhalation and decrease with exhalation in a sinusoidal fashion.”

Respiratory Sinus Arrhythmia

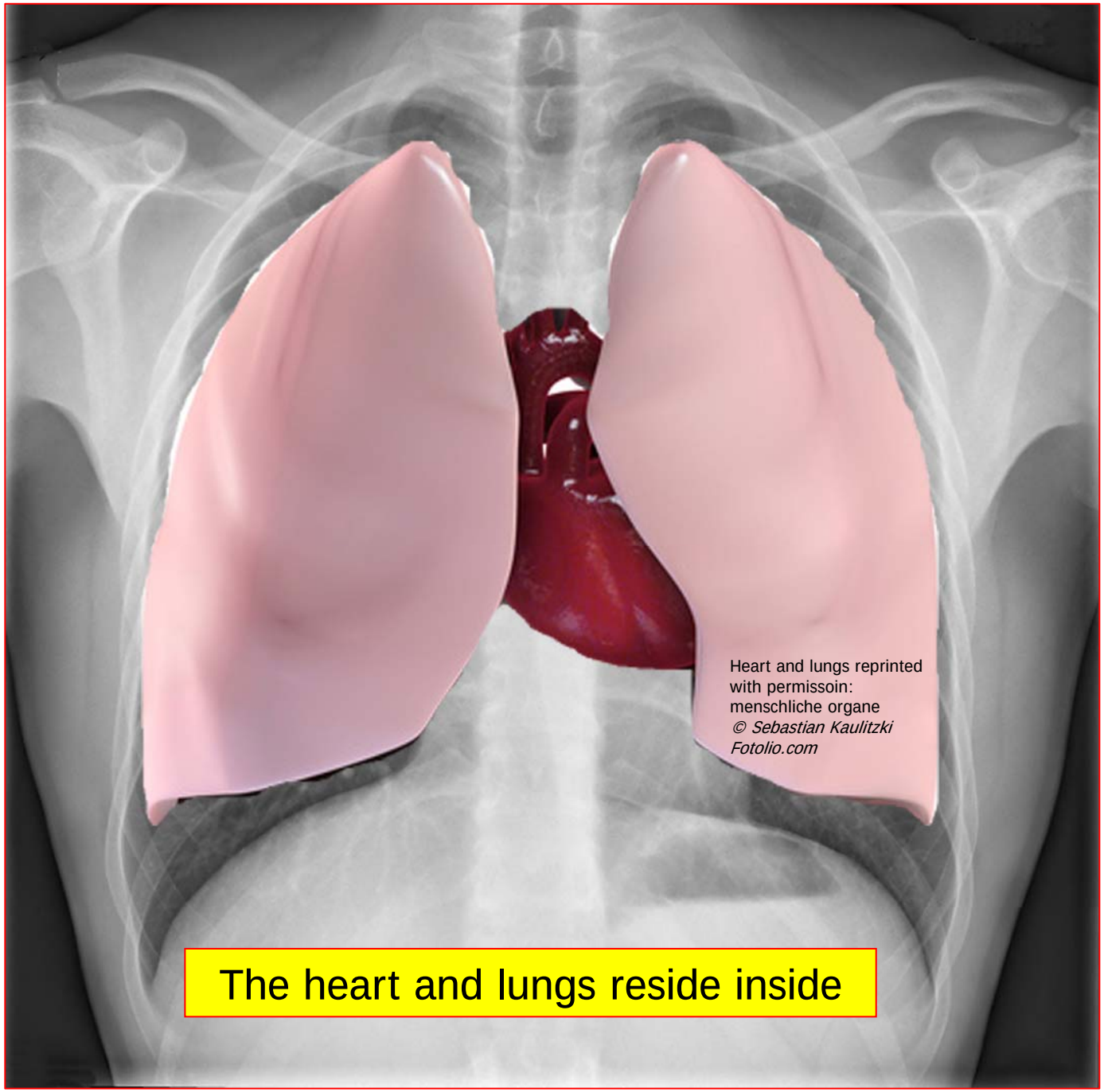
Why?

- For nearly 100 years the answer has been that heart rate changes in response to changes in blood flow and pressure as a consequence of respiration.
- This understanding is fundamentally sound. But we don't know much about it.
- Most of our understanding regarding respiration has to do with "air" and "gas exchange", not blood.
- So, lets look at blood flow and pressure as a function of respiration.

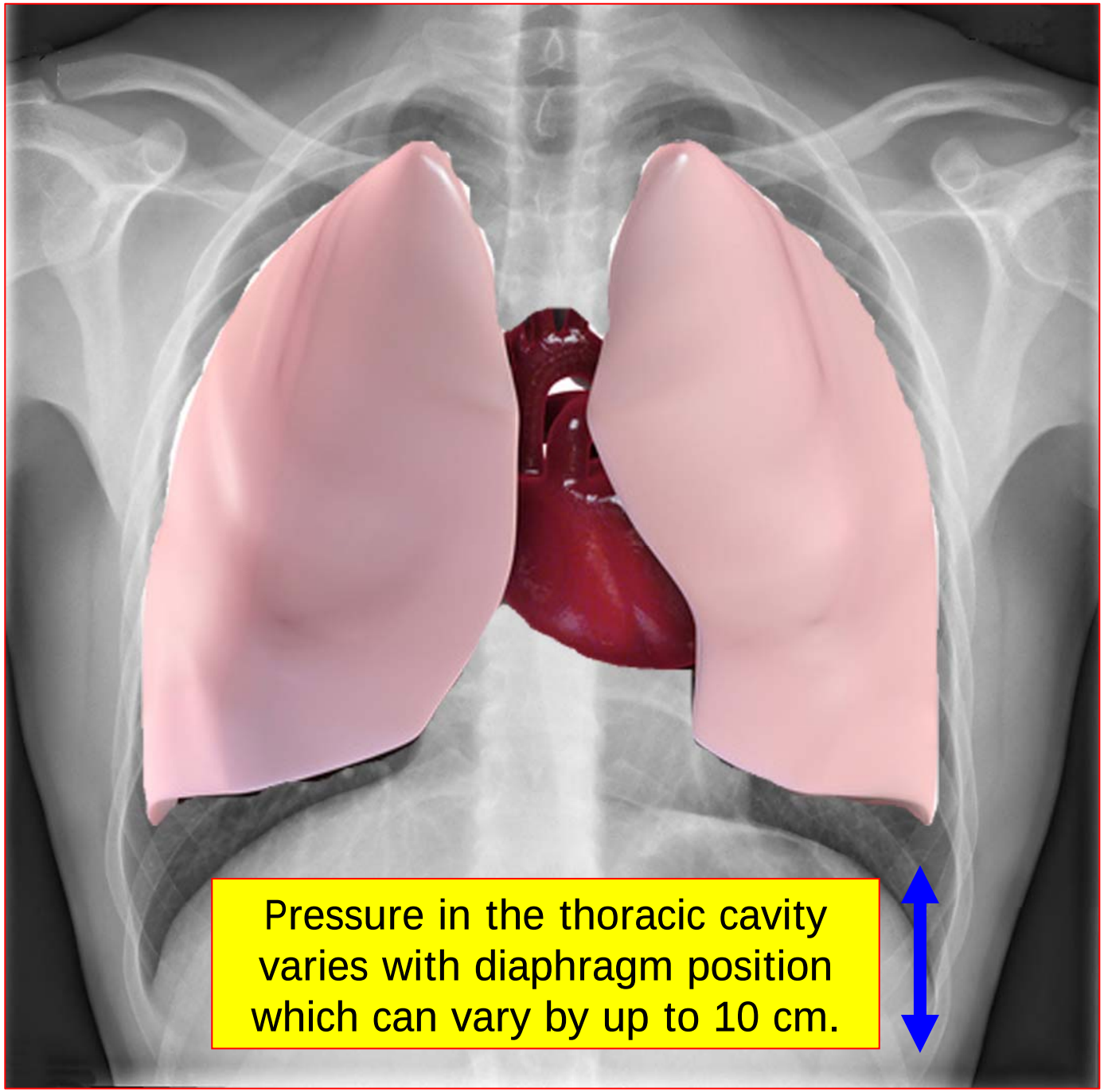
The Thoracic Cavity



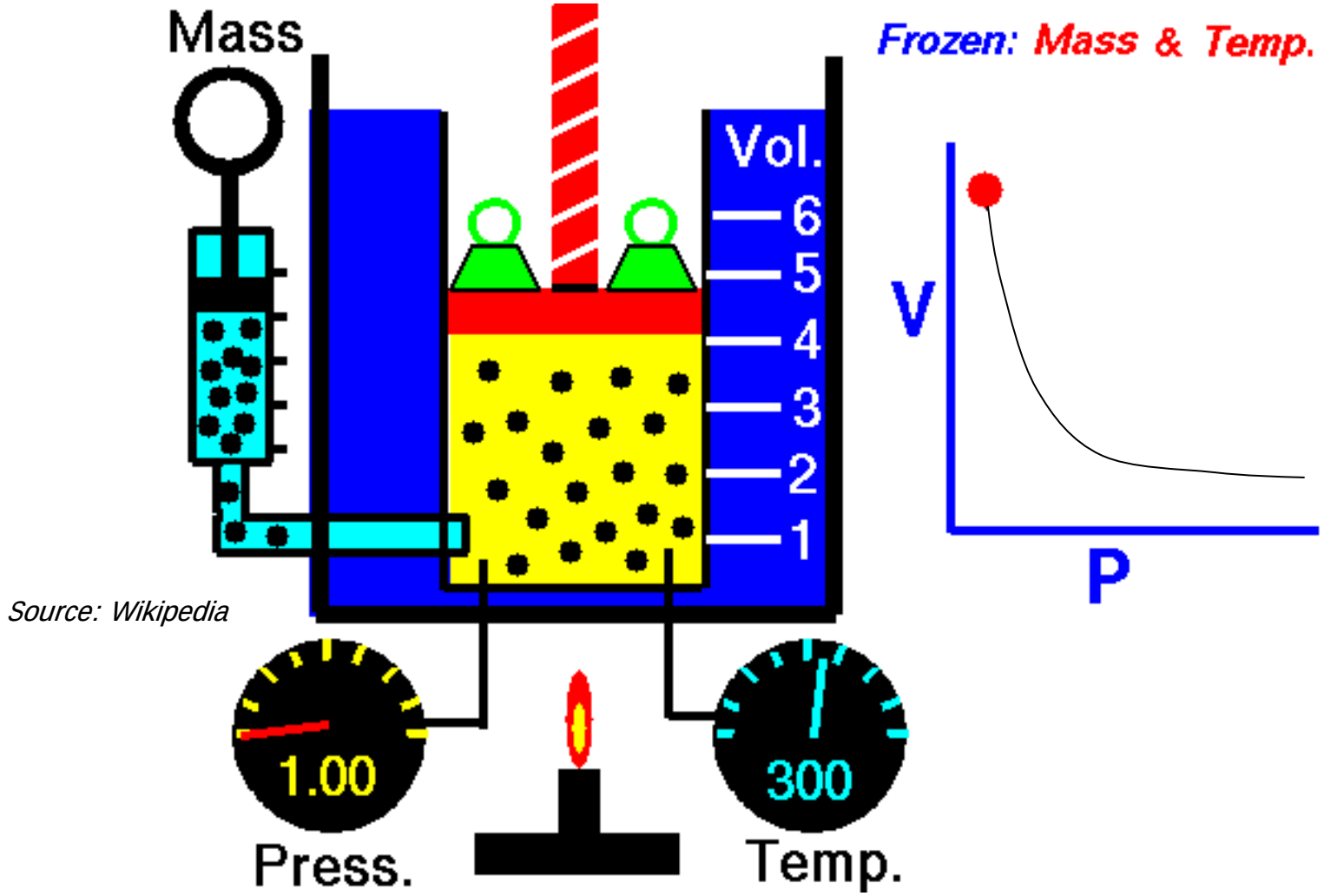
The Thoracic Cavity



The Thoracic Cavity



Boyle's Law

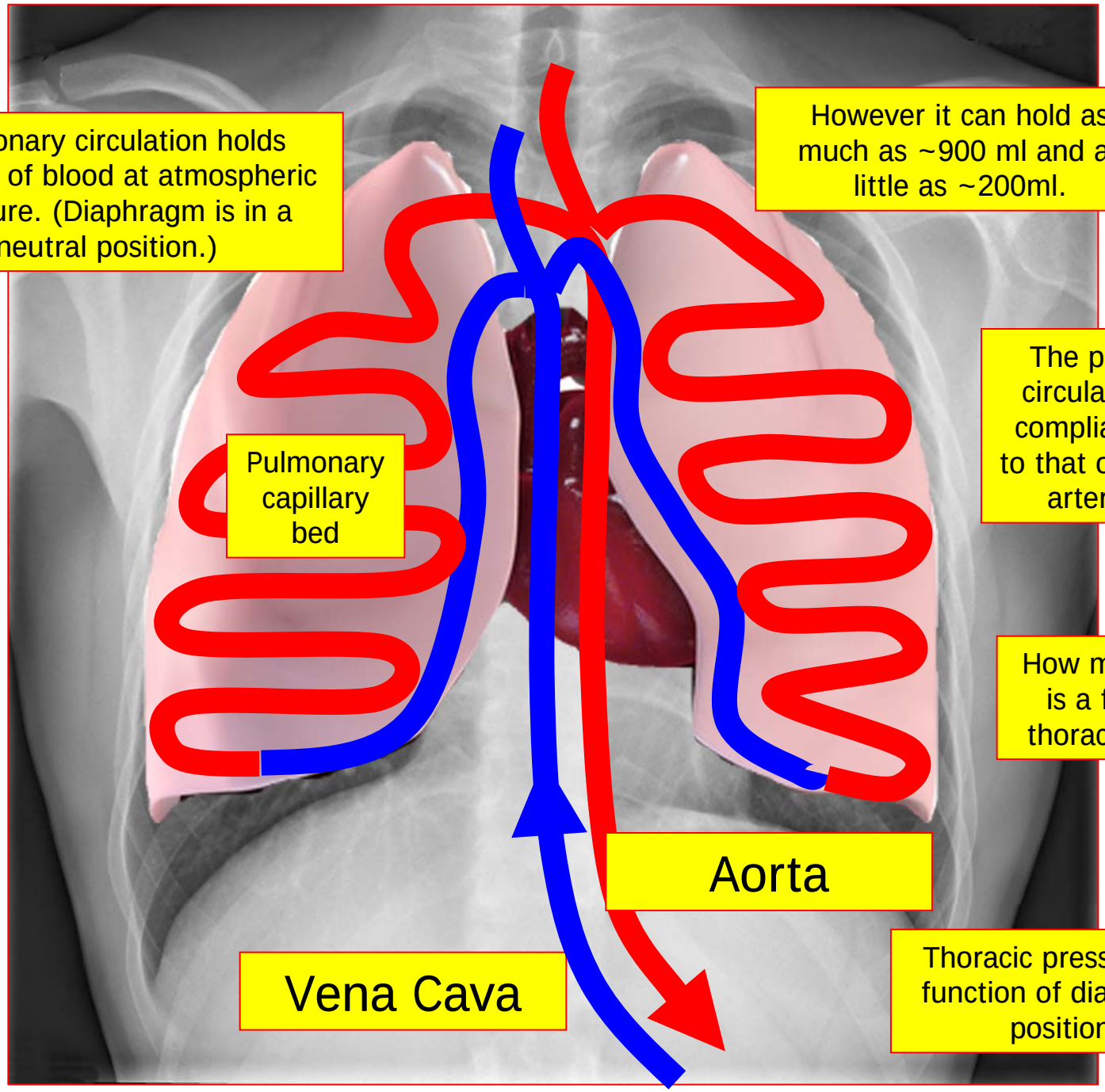


Source: Wikipedia

Boyle's Law: Absolute pressure and volume of a gas are inversely proportional:

- As volume increases, pressure decreases
- As volume decreases, pressure increases

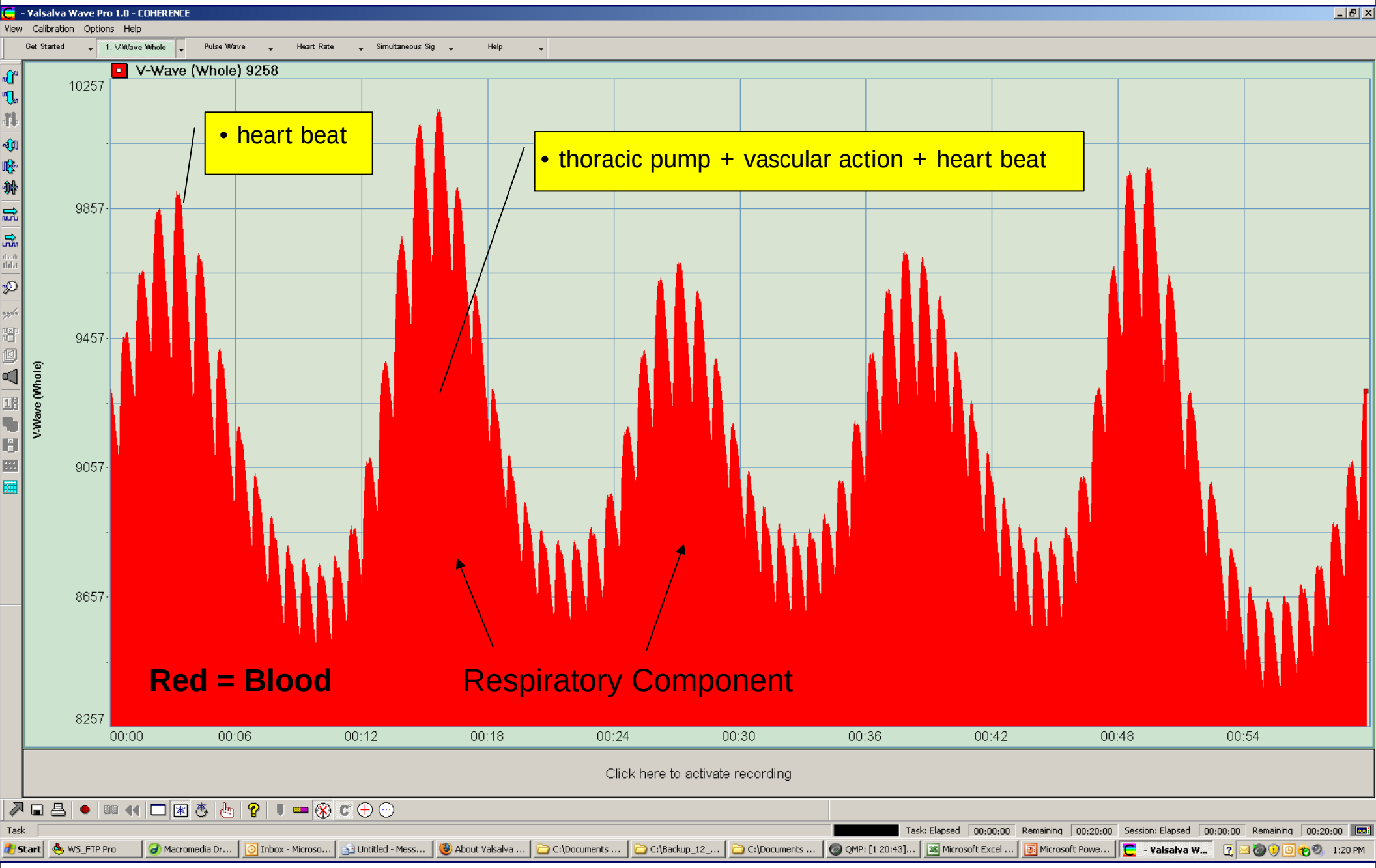
The Thoracic Cavity



anatomy is simplified for purposes of illustration

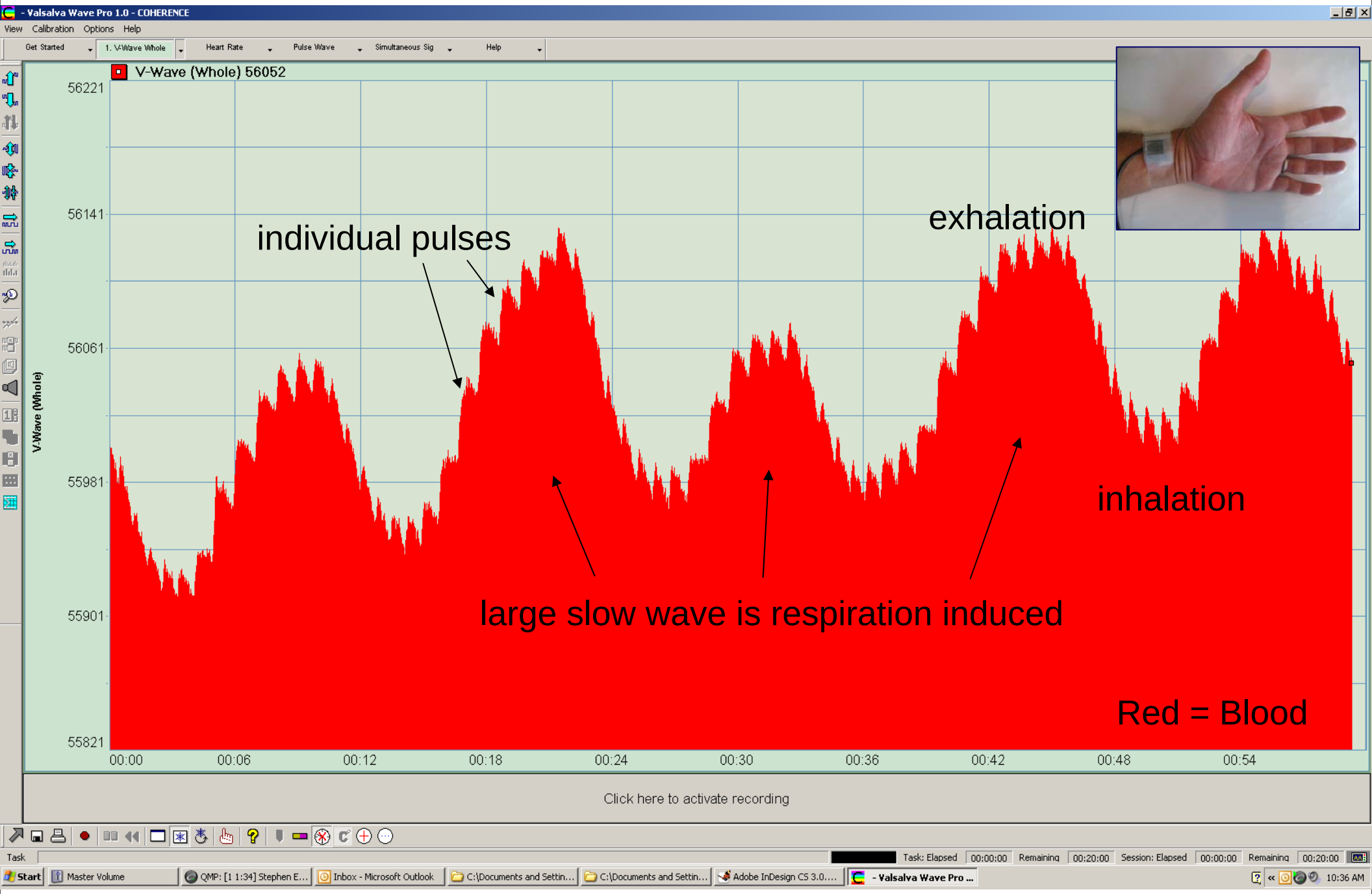
Pulmonary Blood Volume

What Does The Wave Look Like?



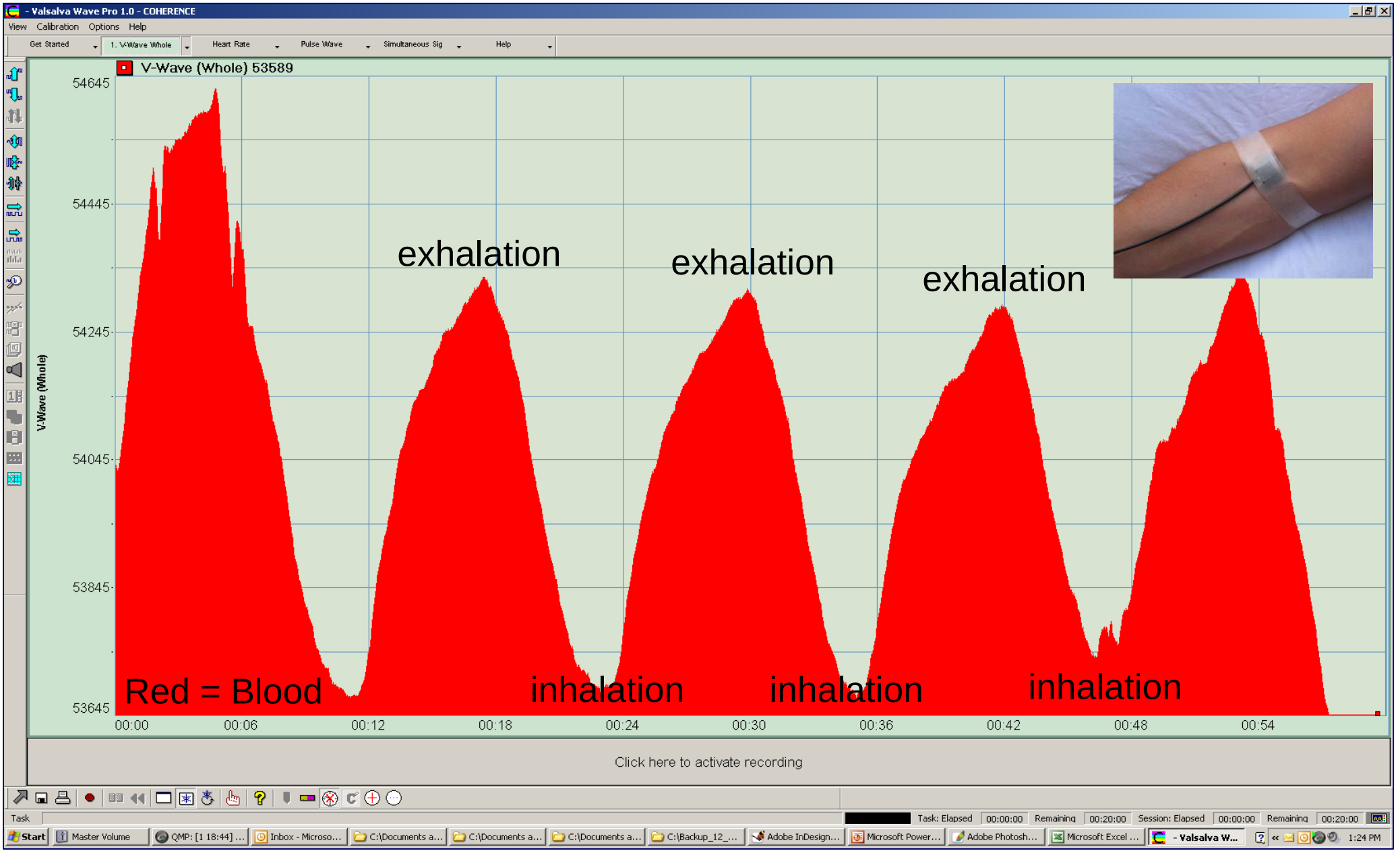
As measured at the ear lobe

Measured At The Radial Artery

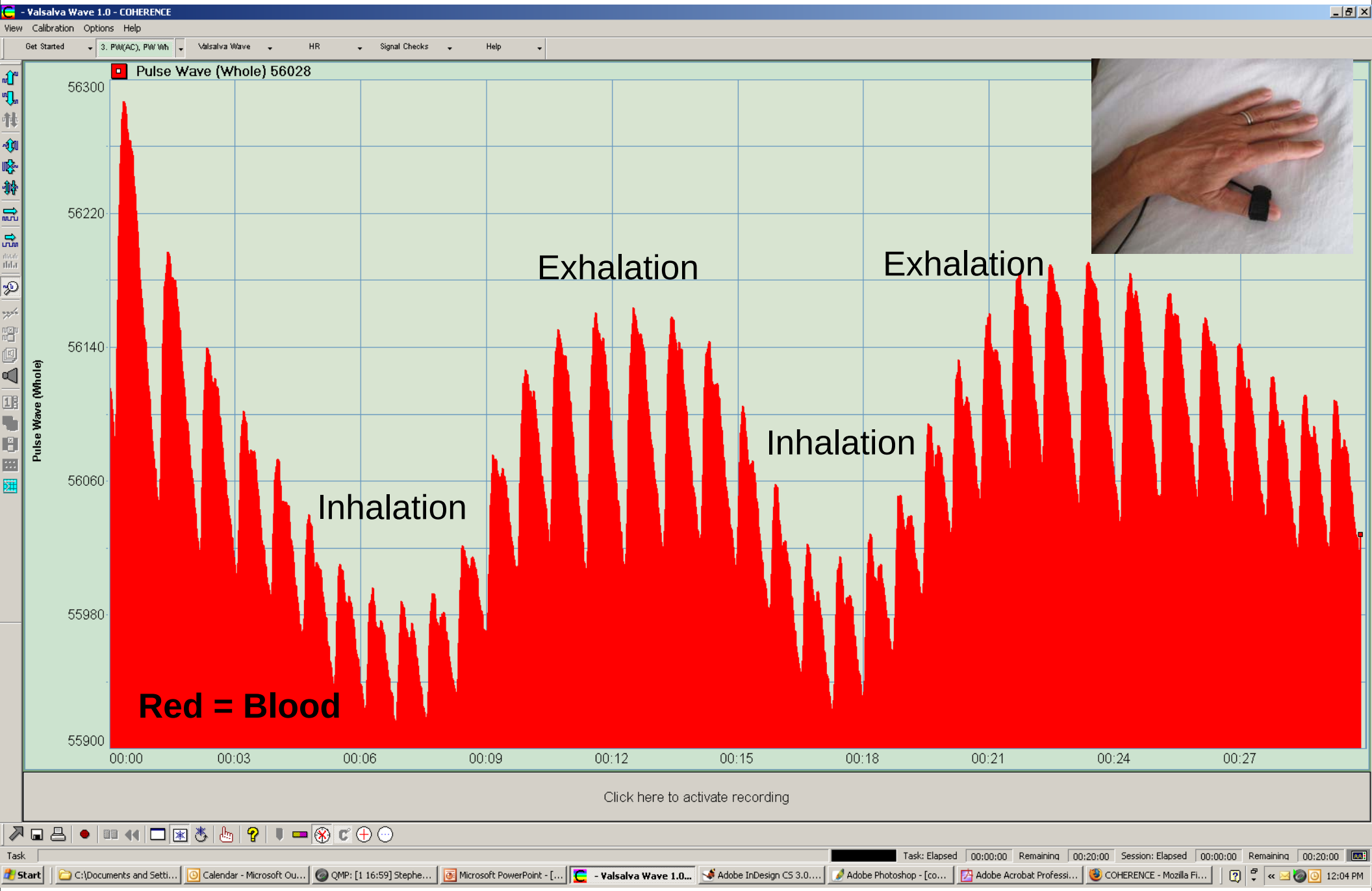


radial artery

Measured At The Medial Cubital Vein

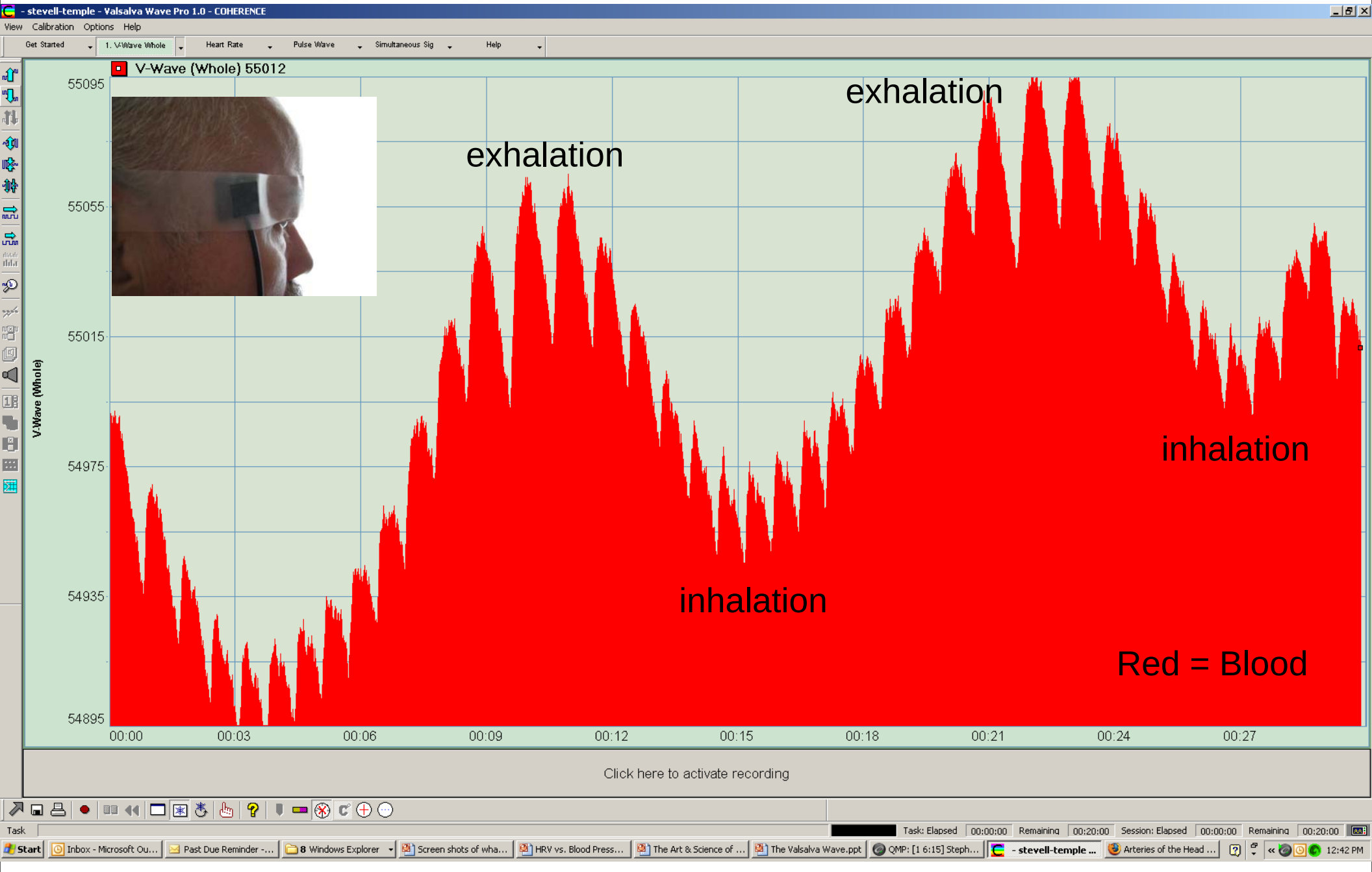


Measured At The Thumb

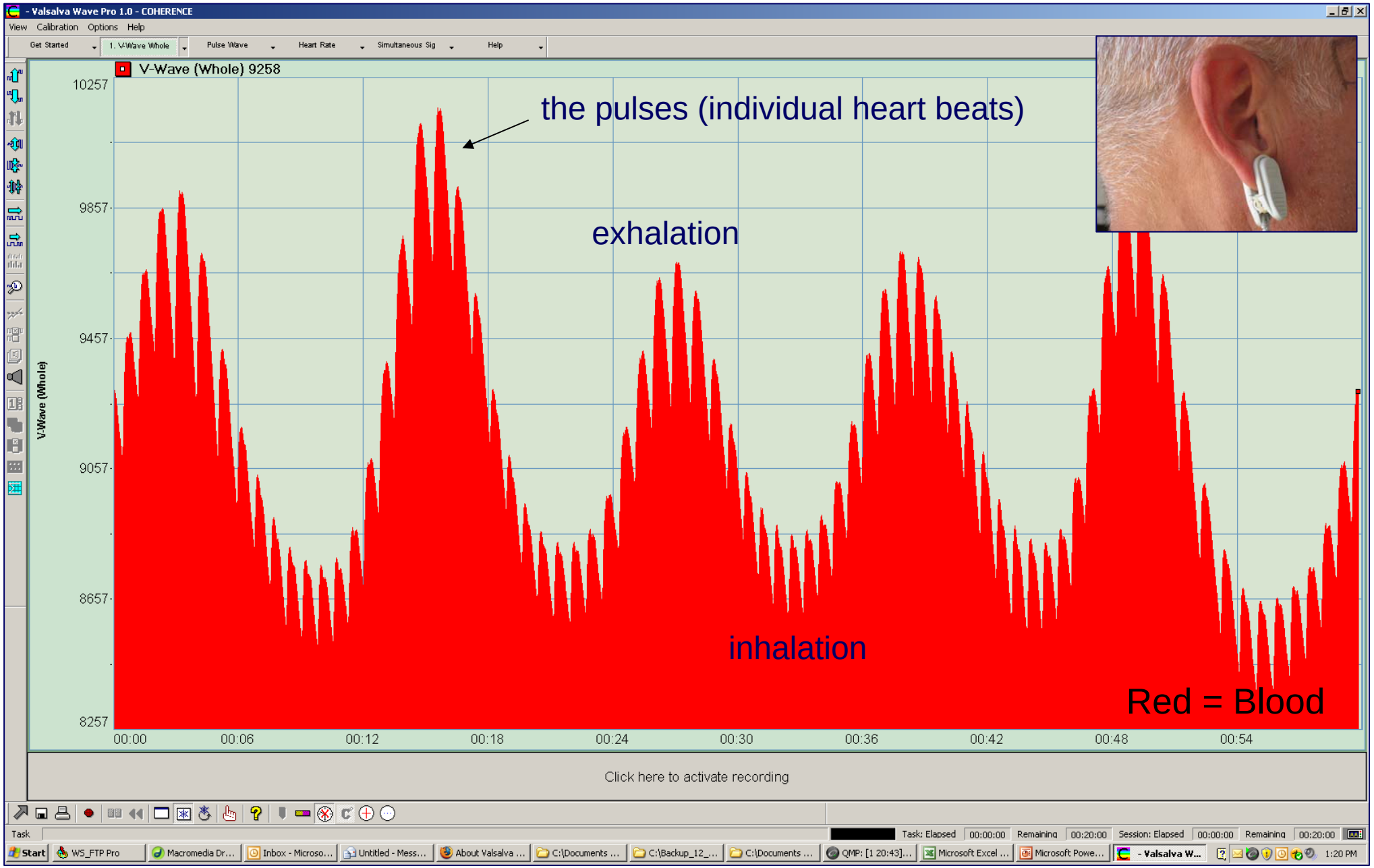


Temple

(Vicinity of Temporal Artery)



Ear Lobe


- Valsalva Wave Pro 1.0 - COHERENCE
View Calibration Options Help
Get Started
1. V-Wave Whole
Pulse Wave
Heart Rate
Simultaneous Sig
Help
V-Wave (Whole) 9258
10257
9857
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V-Wave (Whole)
the pulses (individual heart beats)
exhalation
inhalation
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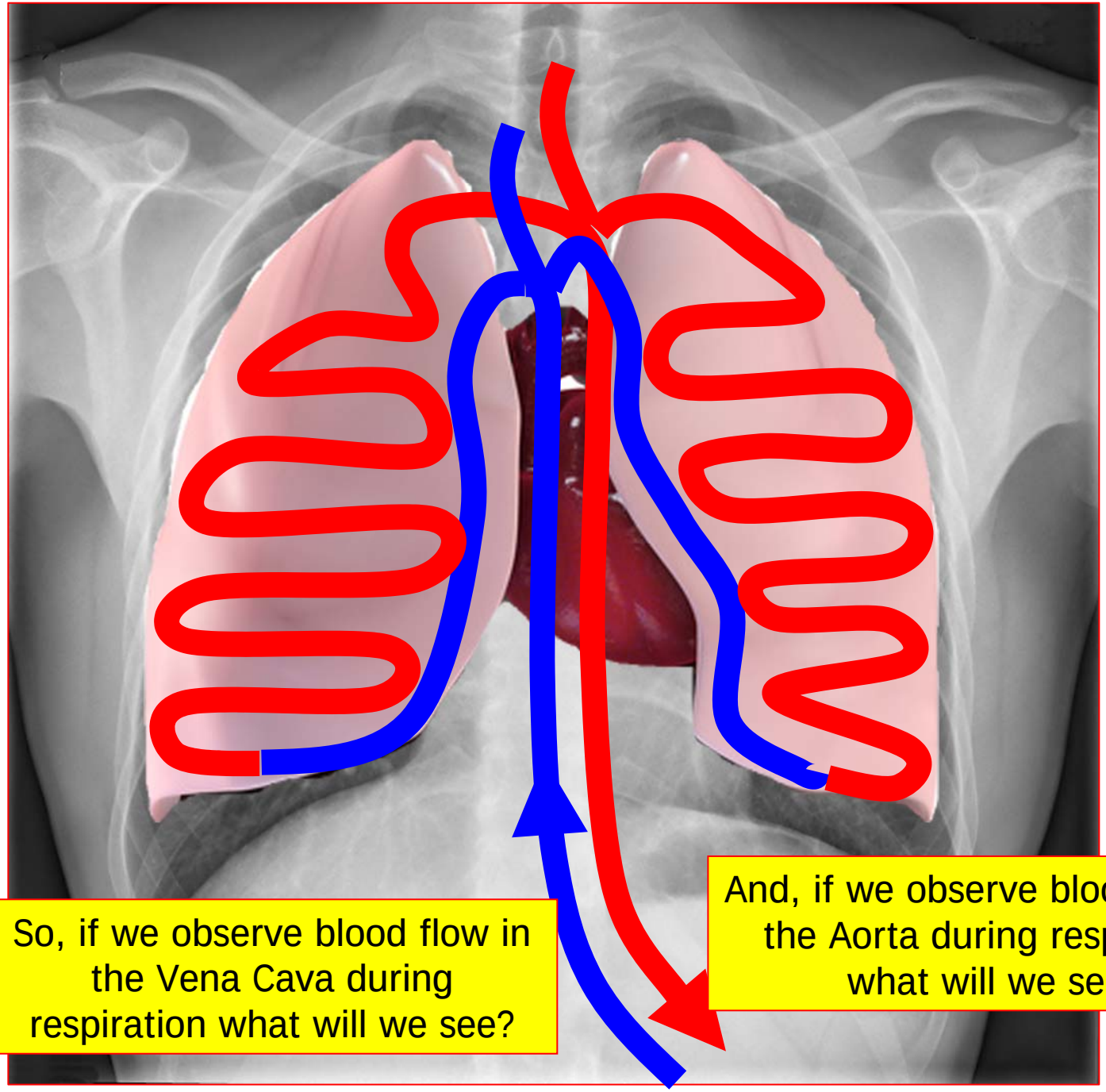
Blood Flow

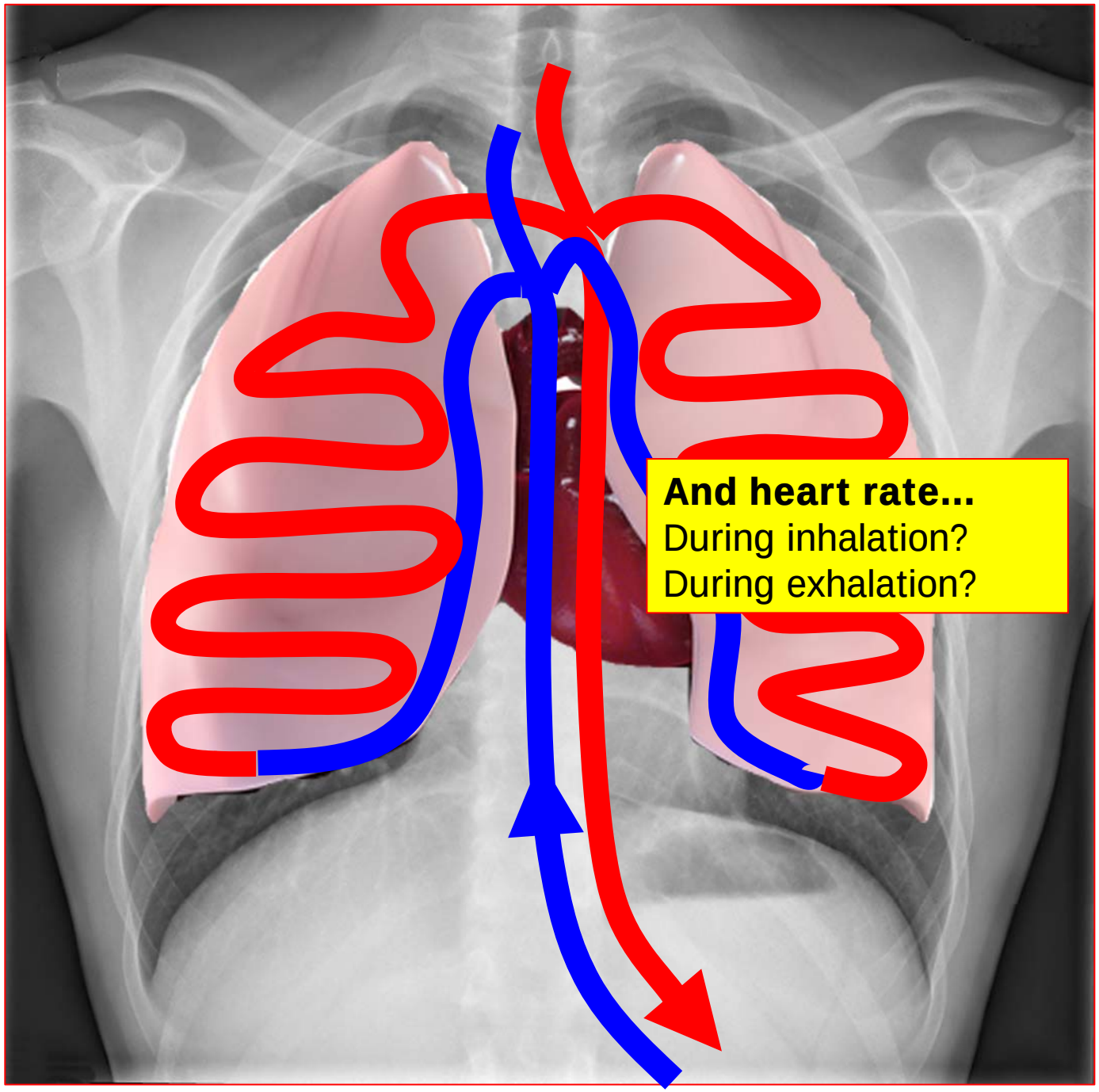


So, if we observe blood flow in the Vena Cava during respiration what will we see?

And, if we observe blood flow in the Aorta during respiration what will we see?

anatomy is simplified for purposes of illustration

And Heart Rate?



anatomy is simplified for purposes of illustration

Heart Rate

Why?

The simple answer….

1. When this much blood (the extreme case) flows into the aorta all at once, if heart rate did not decrease, blood pressure would rise too much.
2. When the lungs are storing this much blood, if heart rate did not increase, blood pressure would fall too much.

Conclusion

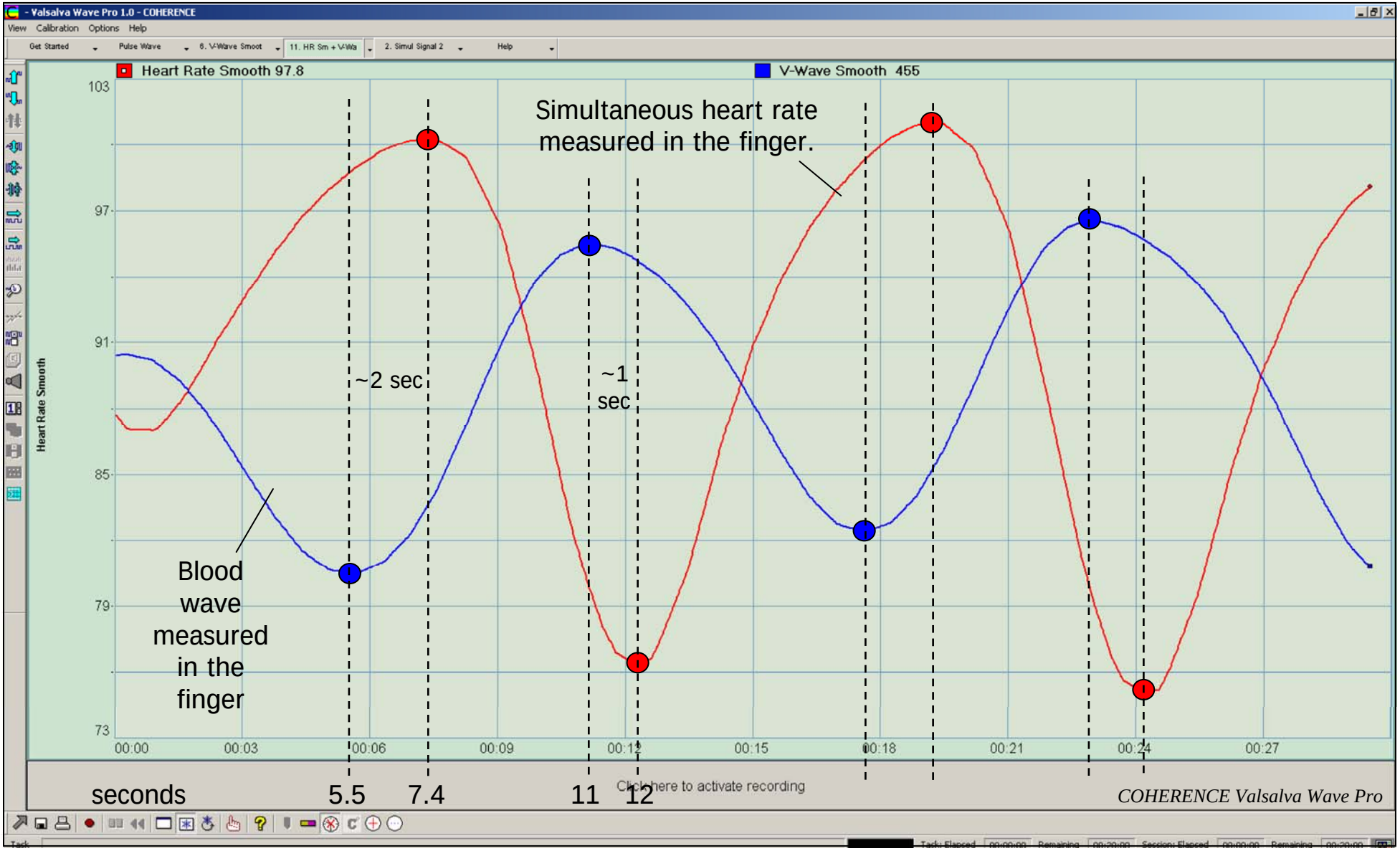
- This supports the theory that “breathing induced HRV” is an outcome of autonomic nervous system regulation of blood flow and pressure.

  [Consistent with the prevailing understanding of Respiratory Sinus Arrhythmia.]

- If this is so, we can expect to see that changes in blood flow and pressure precede changes in heart rate….

And if we look, this is what we see…

If We Look...



We see that changes in the blood wave lead changes in heart rate (at near resonance).

The End

Thank You!

A 10X Relationship?

	A	B	C	D
1	**Physiologic Phenomenon**	**Typical "Shallow" Breathing (10% of VC)**	**Deep Synchronous Breathing (75% of VC)**	**Vital Capacity (4.5L) (75% of total lung capacity)**
2	**Diaphragmatic Movement (Range)**	**1 cm** (10%) Source: Source:Pulmonary Physiology, p.15	**7.5 cm** (75%) Estimated	**10 cm** (100%) Source:Pulmonary Physiology, p. 15
3	**Intrapleural Pressure (Range)**	**2.5 cmH_2O** (8%) (-5 to -7.5 mmH_2O) Source: Medical Physiology, p. 433	**25 cmH_2O** (75%) Estimated	**33 cmH_2O** (100%) Estimated (Can be much higher during forced inspiration)
4	**Inspiratory/Expiratory Volume**	**.5 L** (Tidal volume of typical adult -11% of VC) Source: Pulmonary Physiology, p. 55	**3.4 L** (75% of VC)	**4.5 L** (Vital Capacity) Source: Pulmonary Physiology, p. 55
5	**Respiratory Arterial Pressure Wave Magnitude**	**2 mmHg** (8%) Source: Medical Physiology, p. 193	**20 mmHg** (75%) Source: Medical Physiology, p. 193; Measured by Elliott	**~27 mmHg** (100%) Estimated
6	**Heart Rate Variability Amplitude**	**5.3 beats** (10%) (Source: Measured by Elliott)	**40 beats** (75%) Source: Measured by Elliott	**~53 beats** (100%) Measured by Elliott (60 beat HRVs have been witnessed by others)

Reprinted from *Coherent Breathing – The Definitive Method*, Elliott & Edmonson, 2008.