Announcements 2/23/04

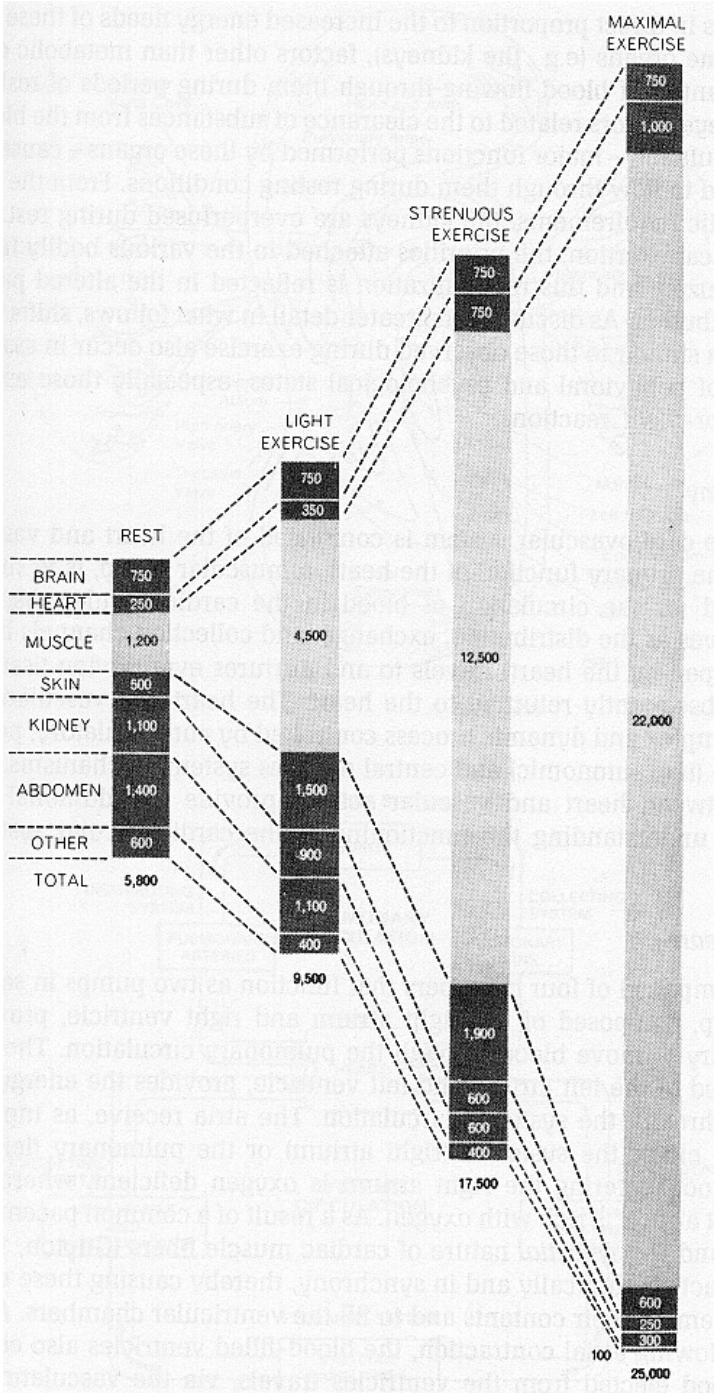
- Electricity test – if you need to retake it, please make sure to schedule time to do so
- 3x5 time

Cardiovascular Psychophysiology

Facts and Functions

- The busy heart
  - Six quarts of blood pumped per minute
  - 100,000 beats per day
  - Try it!
- Functions
  - Transport oxygen from lungs and nutrients from gut
  - Transport waste products
  - Transport regulatory substances (e.g. endocrines)
  - Thermal exchange between core and periphery

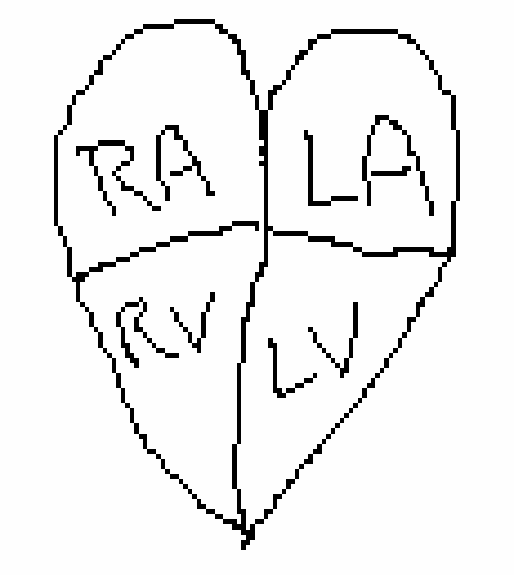
Metabolic Demands



Anatomy of the Heart

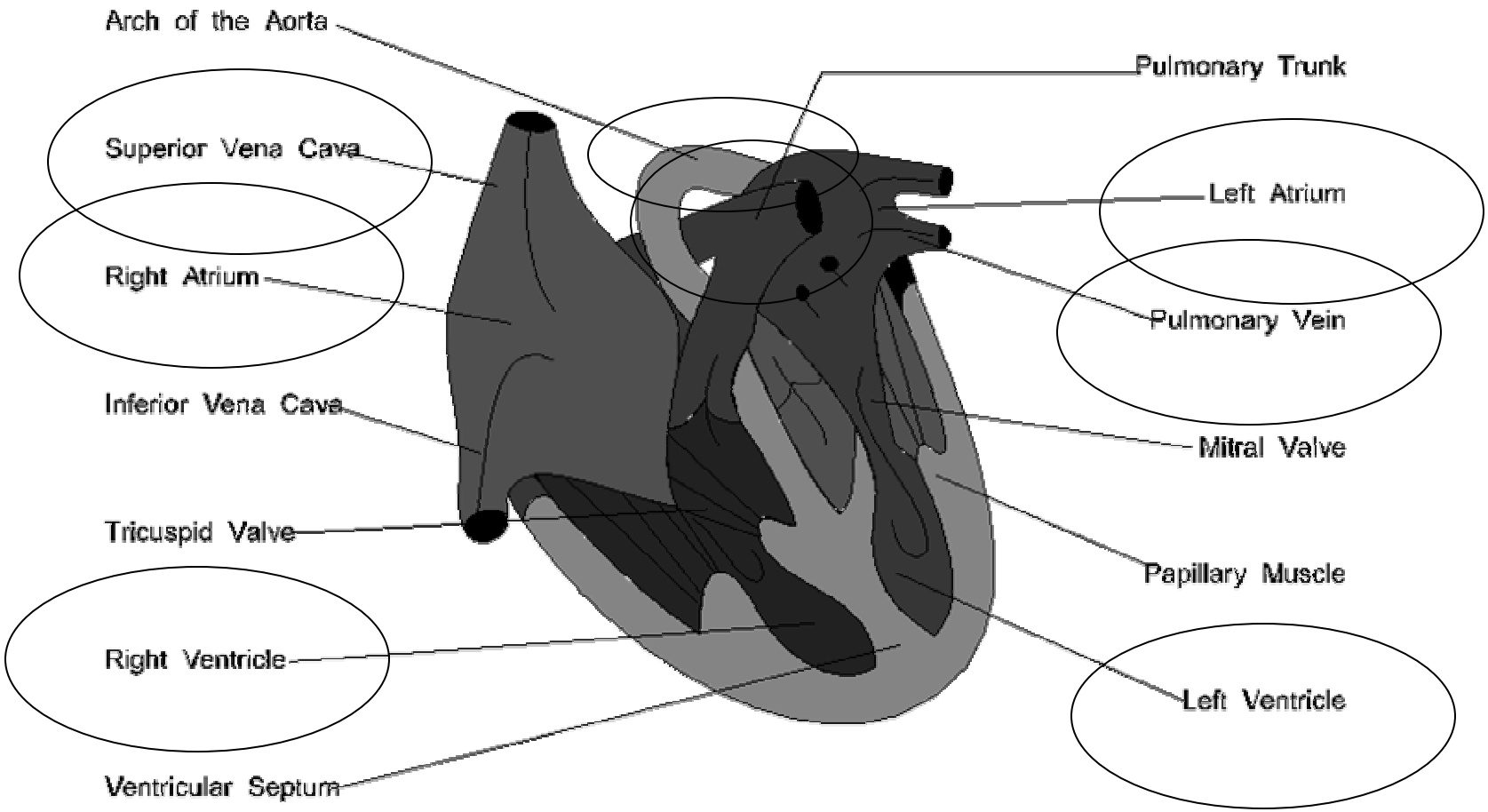
- Cardiac Muscle (myocardium)
  - not striated, not smooth
  - four features distinguish from smooth or striate
    - Muscle has unstable resting potential – basis for intrinsic and rhythmic contraction
    - Action potential freely conducted from one cell to another (lattice-like syncytial) network of cardiac fibers
    - Repolarization lasts about 100 msec
    - Contraction phase = to duration of cardiac action potentials

- Four chambers
  - Right Atrium
  - Right Ventricle
  - Left Atrium
  - Left Ventricle

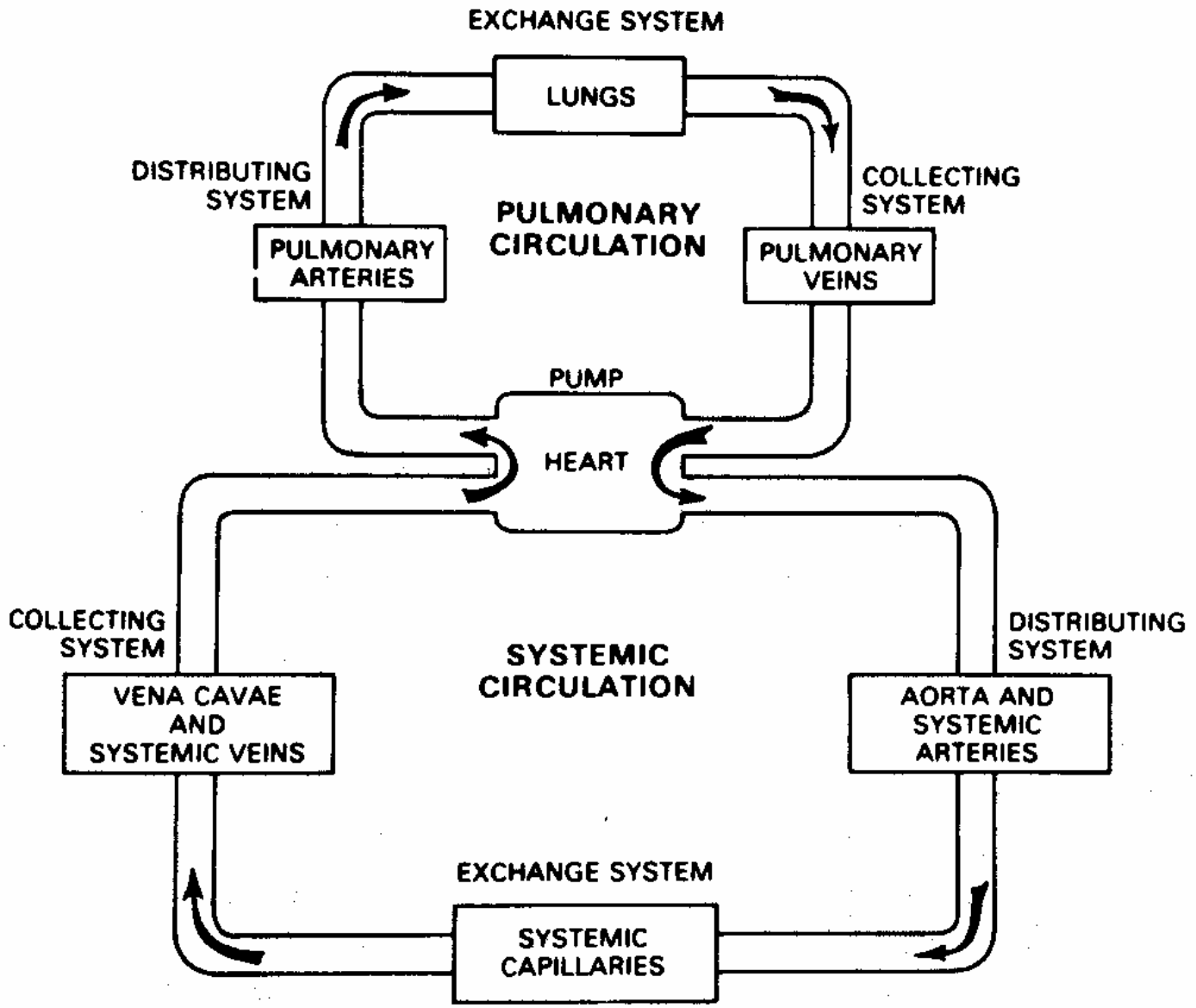


Anatomy of the Heart

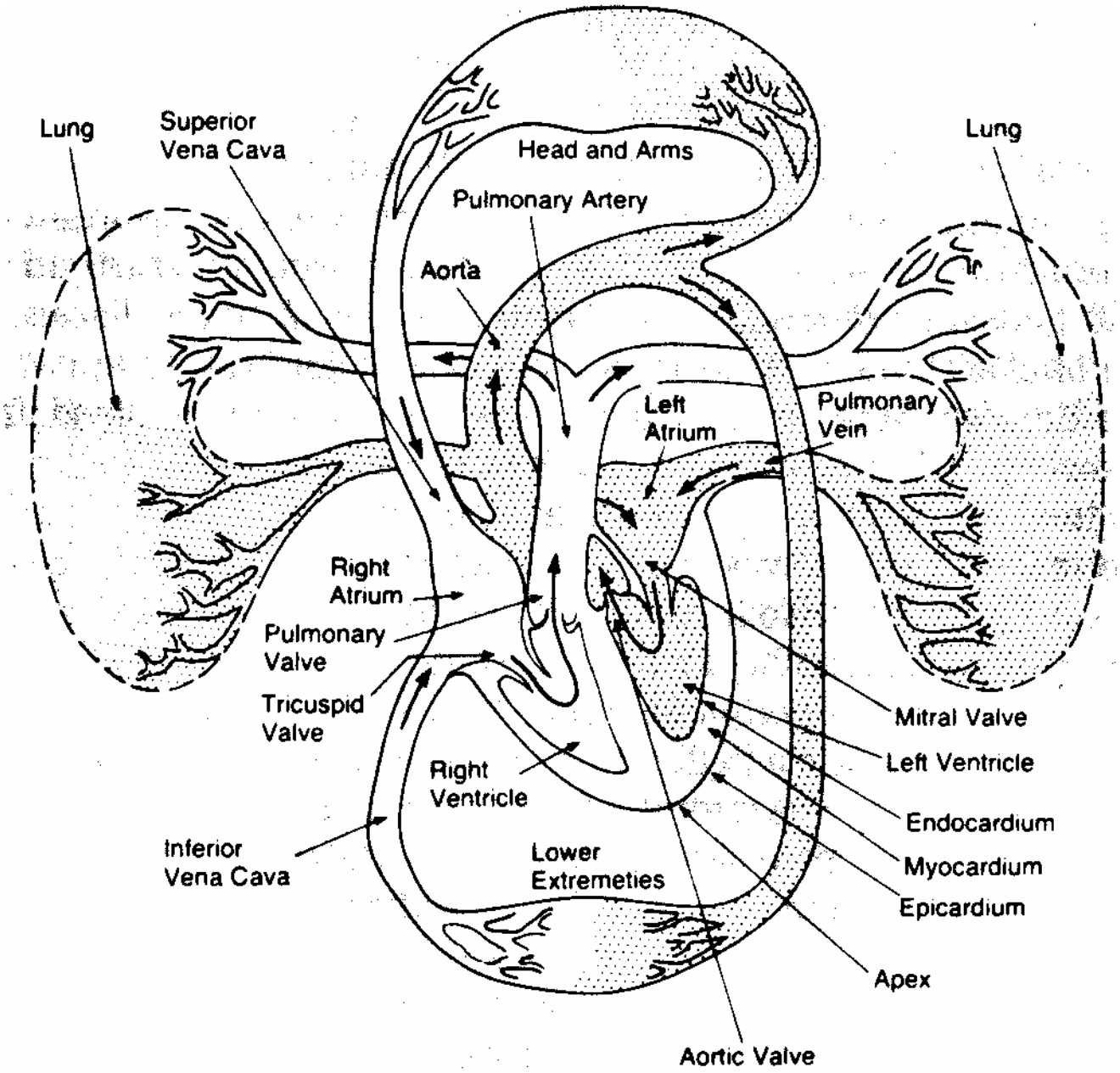
Heart



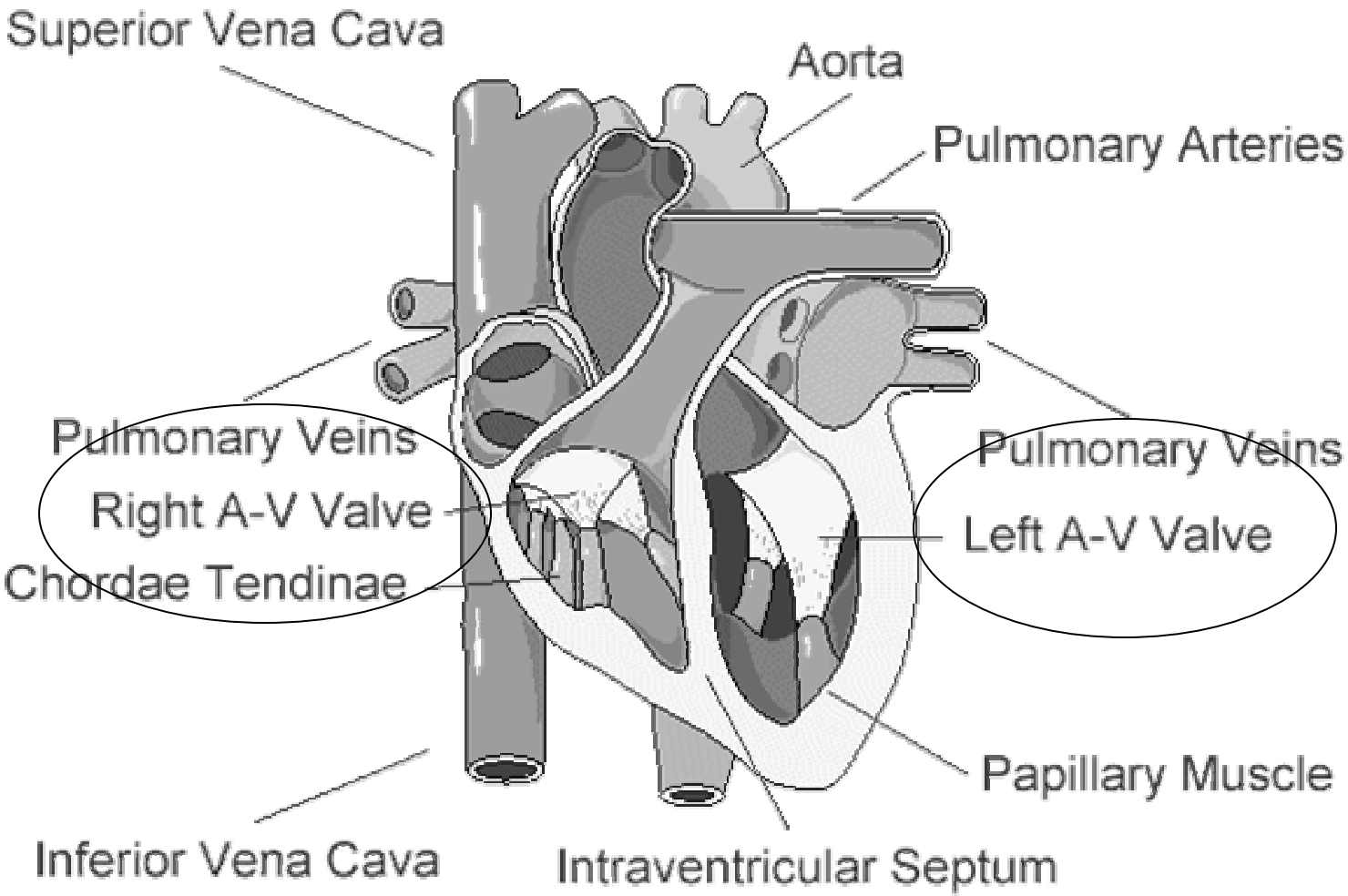
Human Circulatory System



Circulation in detail



Anatomy of the Heart



More Valves

- Aortic and Pulmonary Valves
  - Respond to relative pressure difference between ventricles and aorta or pulmonary artery
  - As ventricles contract, pressure builds, and forces valves open when pressure exceeds arterial pressure
- "Dub" in the Lub-Dub sound

Neural Conduction of the Heart

- Two Nodes
  - Sino-Atrial (SA) node – “Primary Pacemaker”
  - Atrial-Ventricular (AV) node – “Yoked”

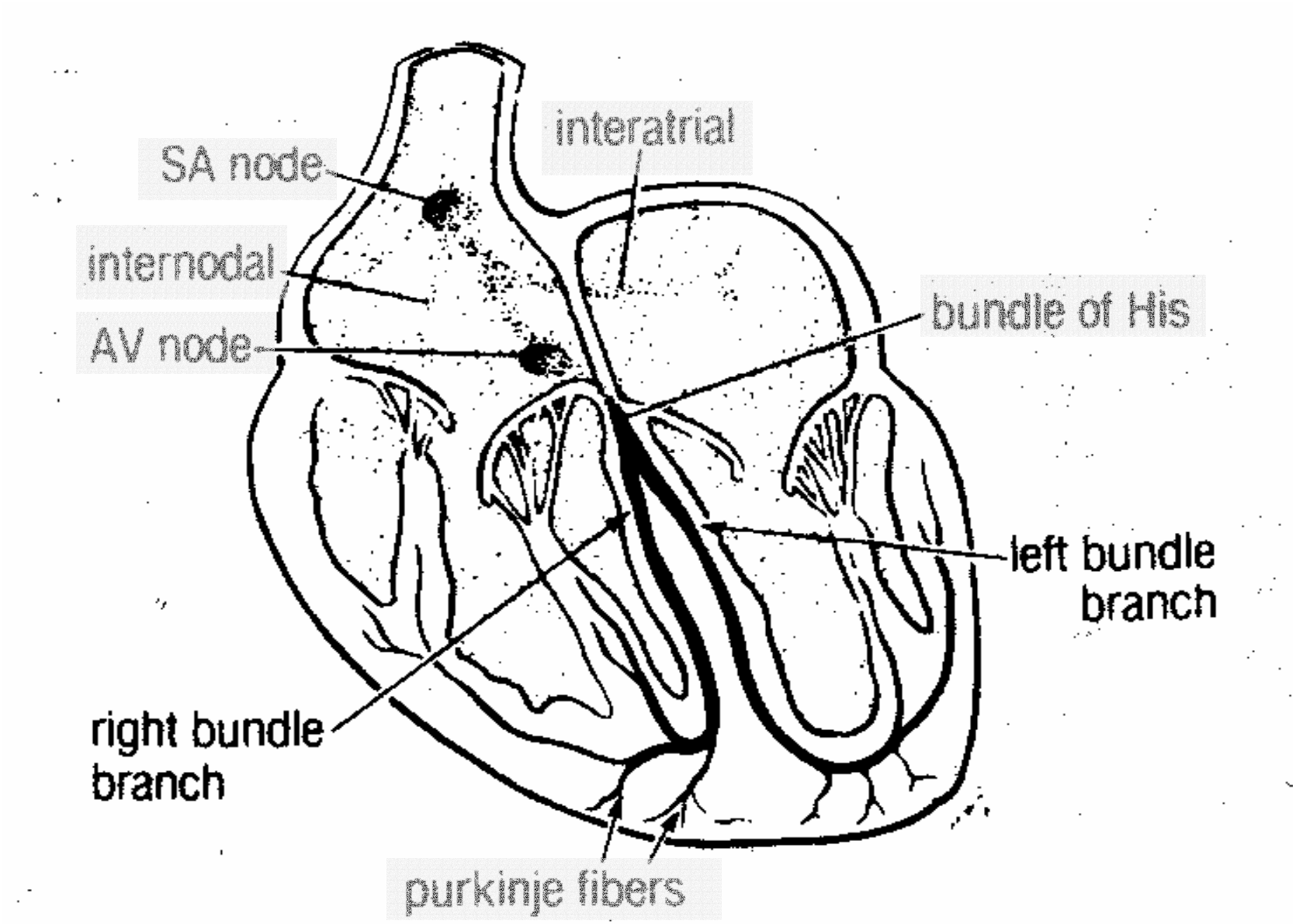
- Nodes have intrinsic rythmicity
  - SA node: 105 bpm
  - AV node: 40-60 bpm

- Denervated heart would still beat at over 100 bpm
  - Must be extrinsic influences to slow or speed heart

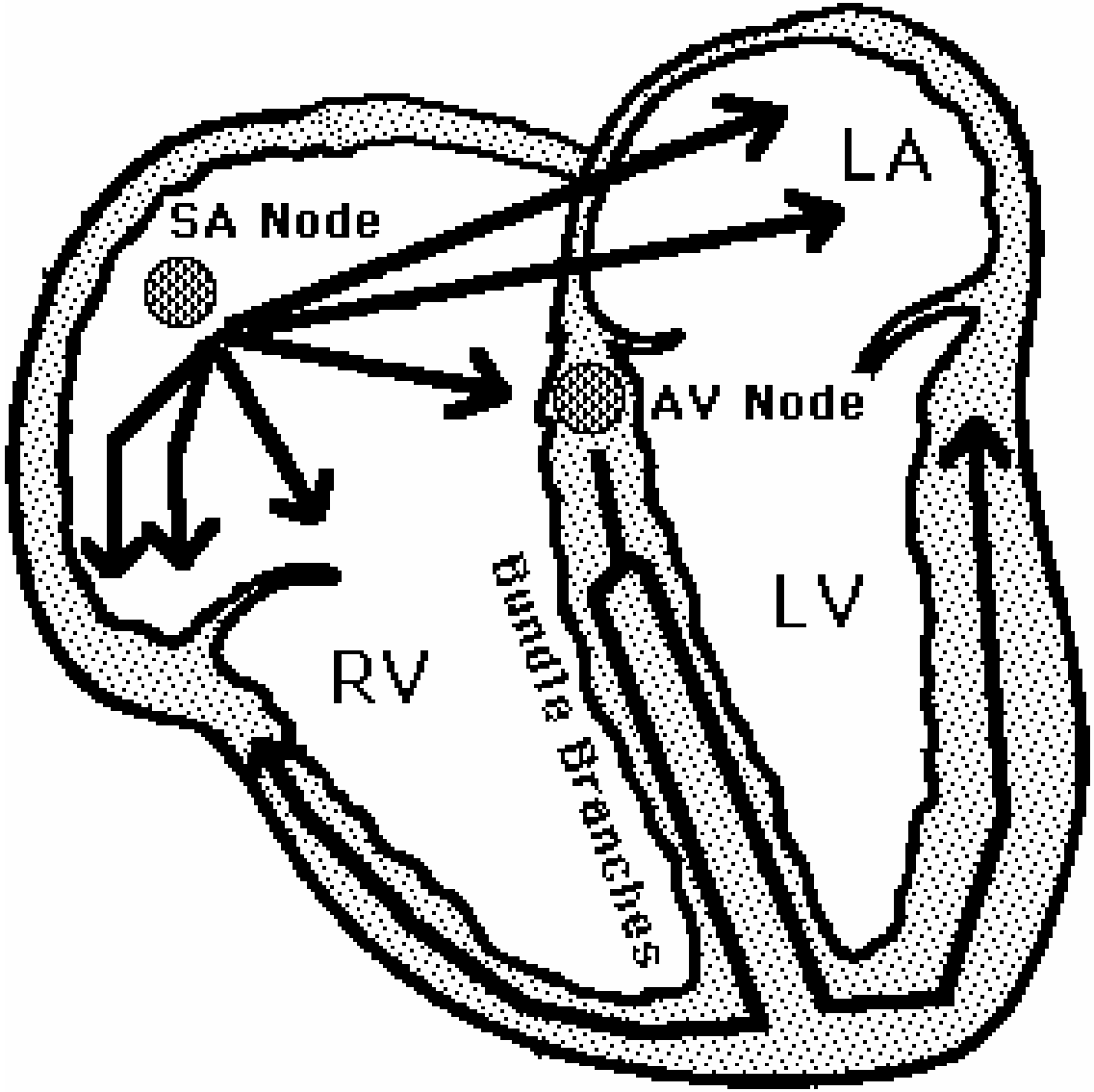
Neural Conduction of the Heart

- Hierarchy ensures that normally the SA node “drives” the system
  - AV nodes provide a critical delay (allows atria to fully contract before ventricles do)
  - AV nodes have important refractory period to prevent rapid successive ventricular contractions
- A coordinated wave of depolarization
  - Contraction of 4 chambers of heart must be precisely choreographed

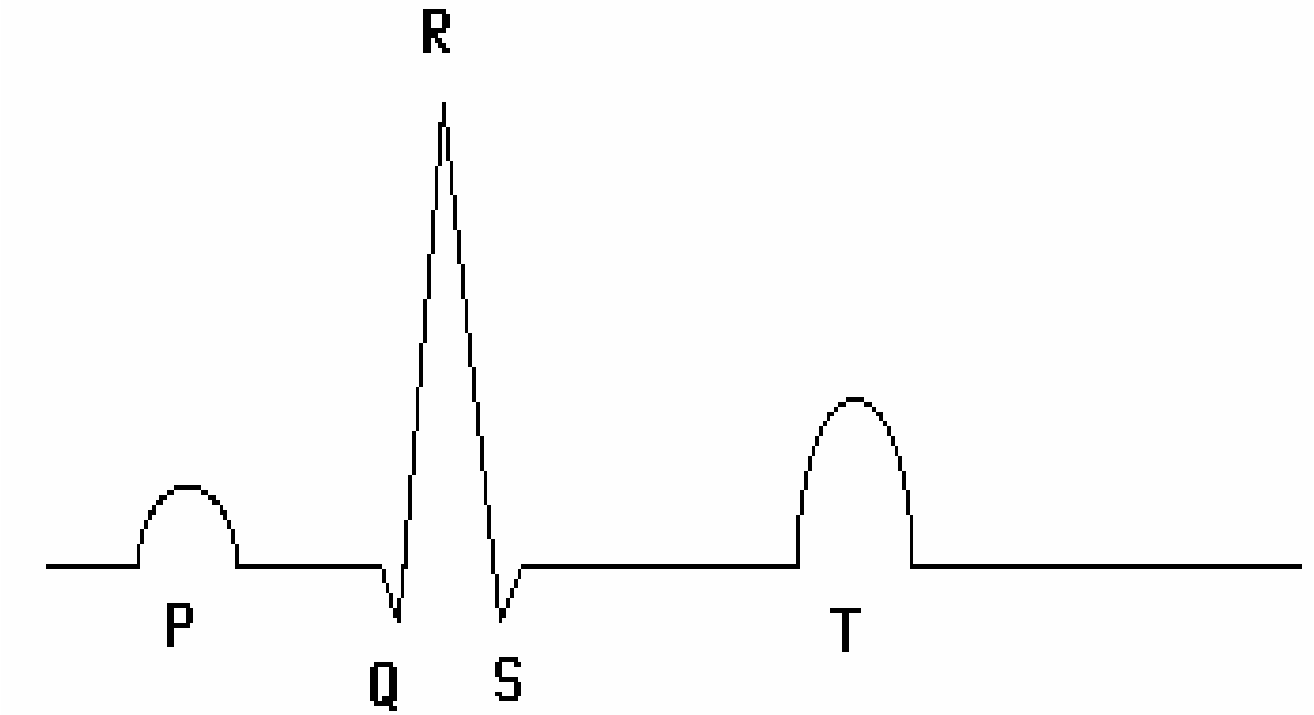
Nodes and Fibers



The SA and AV Nodes in Action

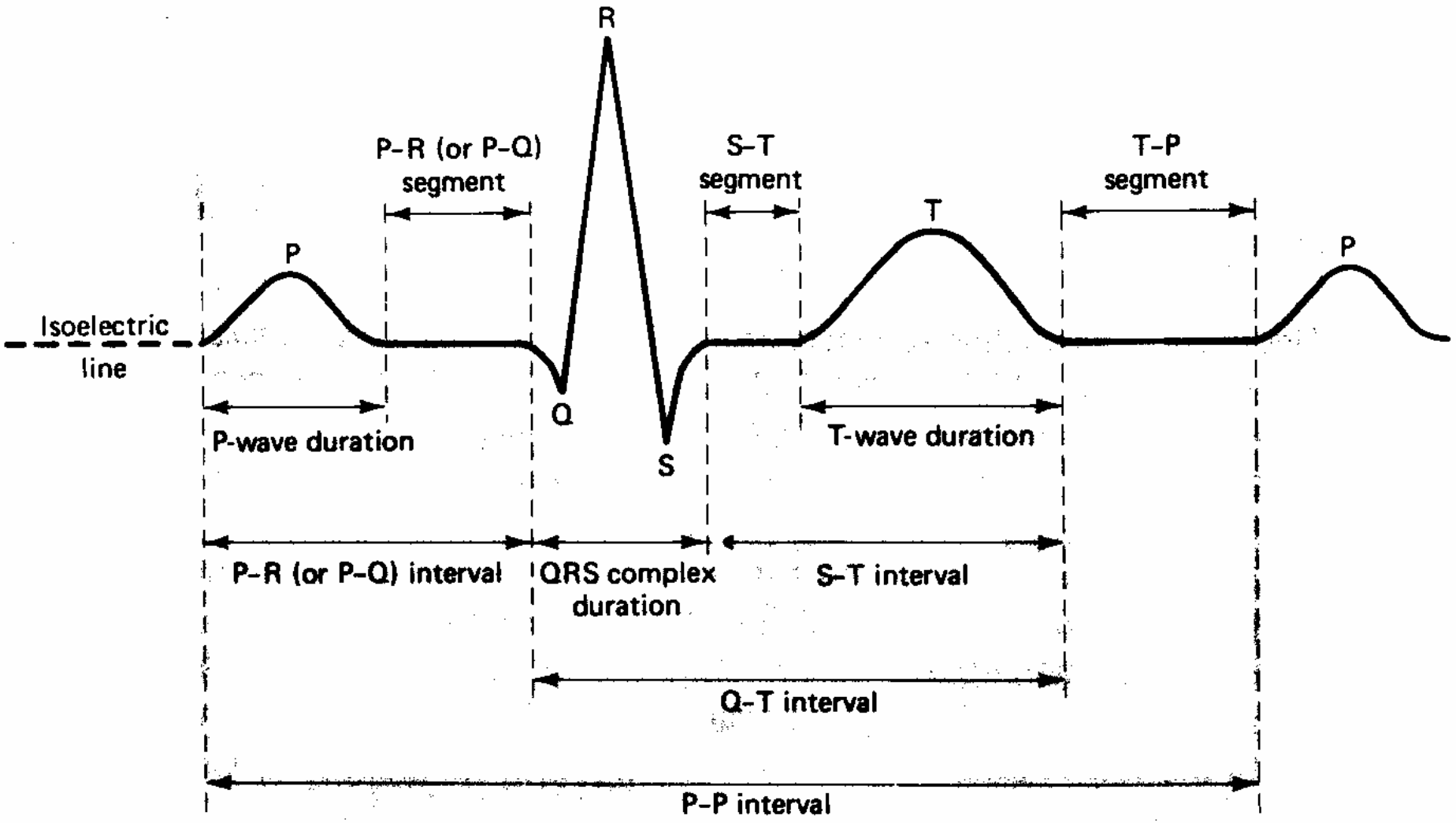


The Schematized EKG waveform

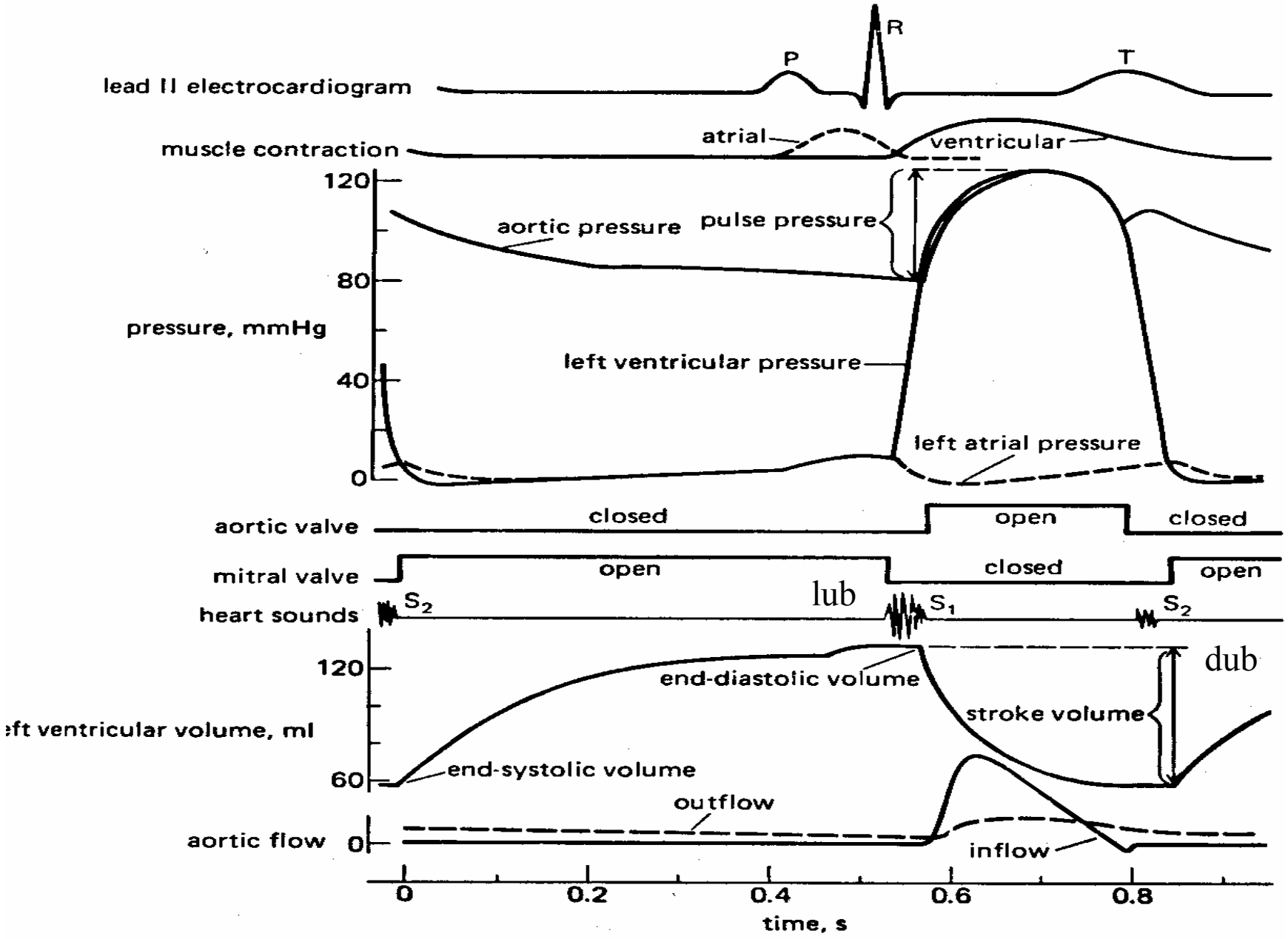


P = Atrial depolarization
QRS = Ventricular depolarization
T = Ventricular repolarization
Note that Atrial repolarization is not visible

The EKG waveform



The Cardiac Cycle

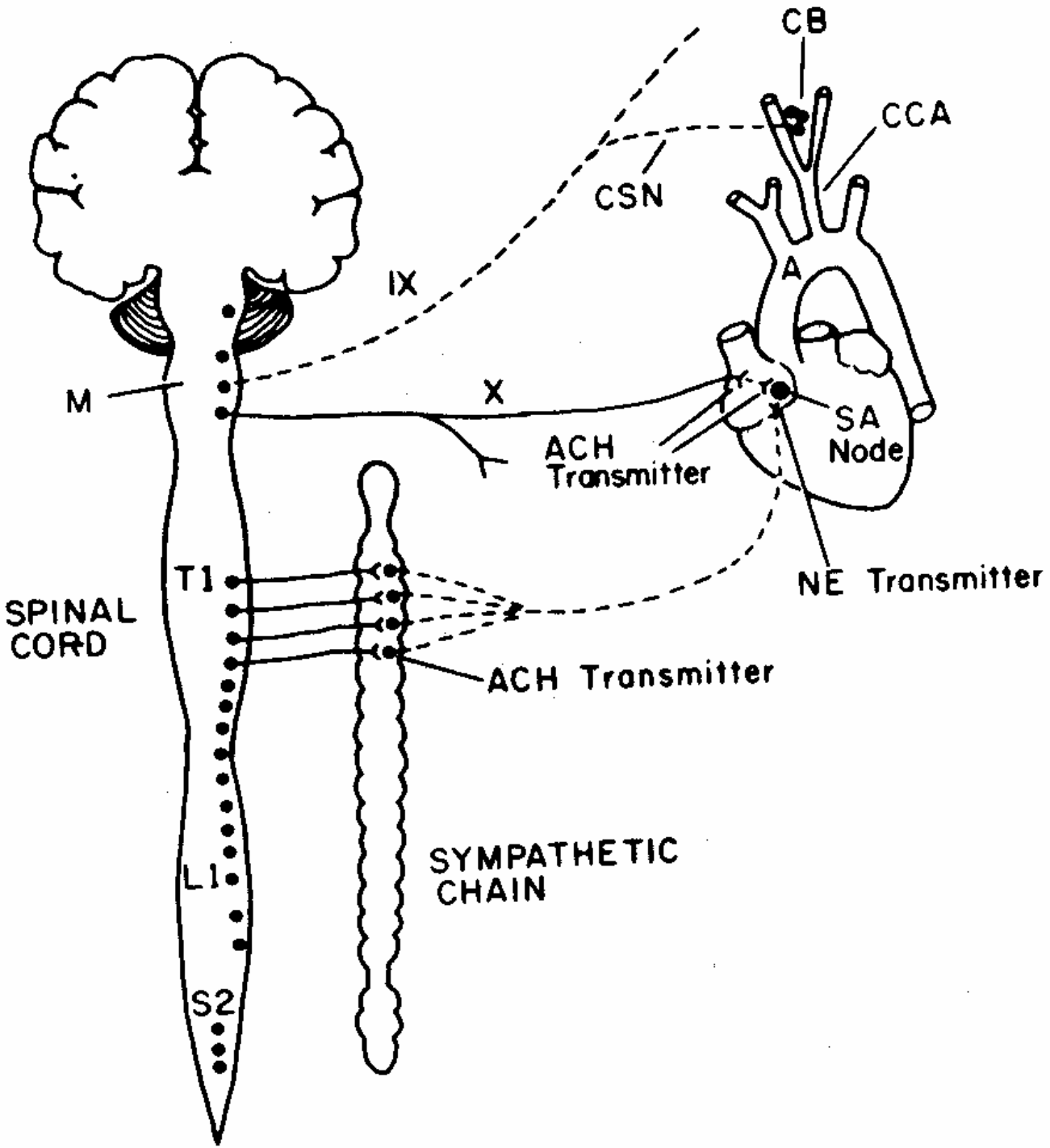


Cardiac Output

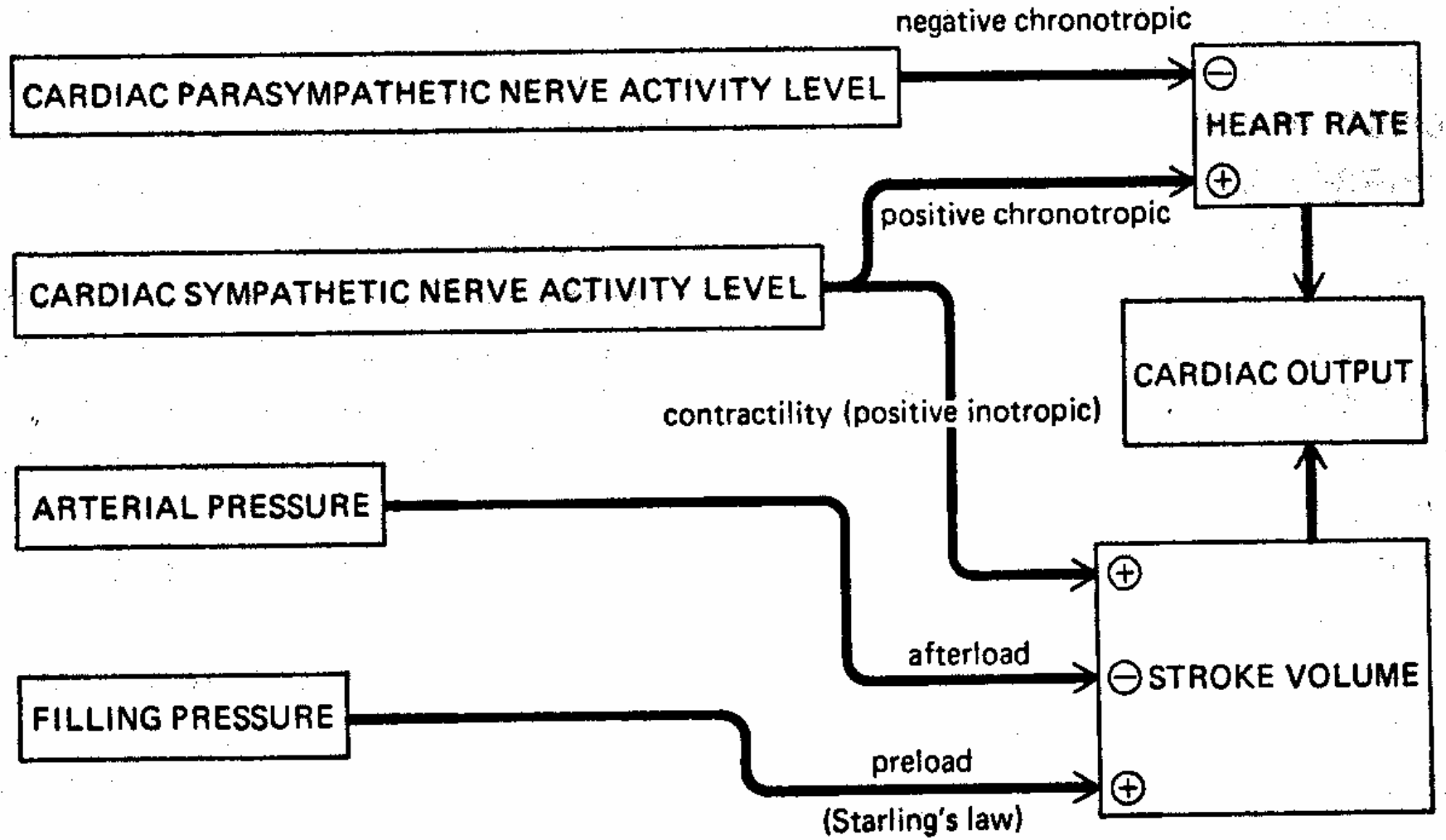
$$CO = HRxSV$$

Cardiac Chronoptropy

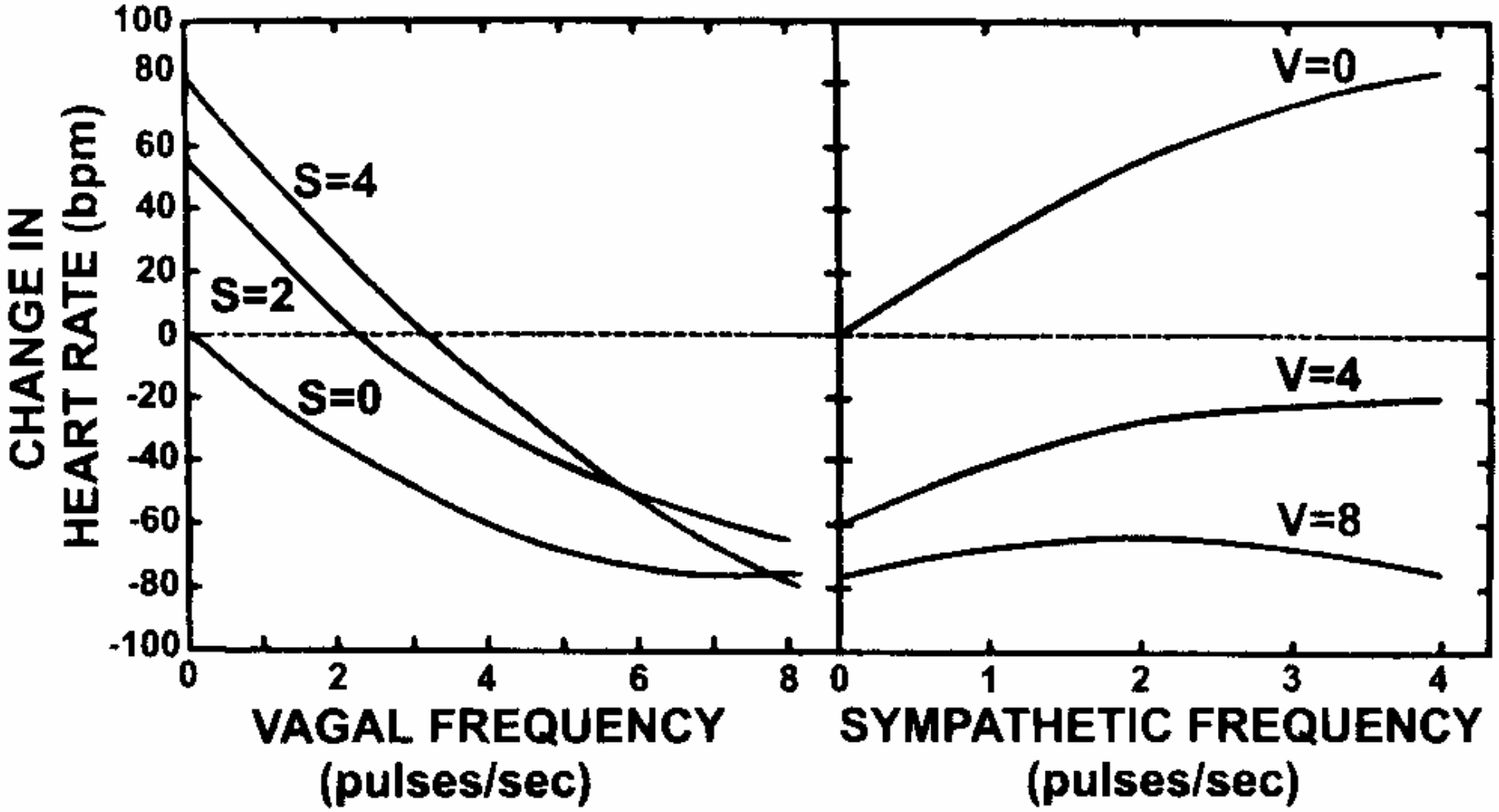
- Heart rate regulated extrinsically
- Vagal (PNS) influence
  - Slows HR
  - So too will dripping ACH on SA node ☺
  - Likely that all changes below 100 bpm are predominately vagally induced
- SNS influence
  - Speeds HR, but impact not as strong as PNS
  - Main effect is to increase contractility


CB
CCA
CSN
IX
A
M
X
SA
Node
ACH
Transmitter
NE Transmitter
T1
SPINAL
CORD
ACH Transmitter
SYMPATHETIC
CHAIN
L1
S2

SNS and PNS influences



HR change to simultaneous vagal and sympathetic stimulation



Integrated Control Mechanisms

- Baroreceptor Reflex
  - Pressure sensitive receptors
  - located in the arch of the aorta and carotid sinus nerves
  - Join Vagal and Glossopharangeal nerves
  - Terminate in regulatory centers in medulla
  - With increase in BP, causes compensatory decrease in HR, contractility, and SV
  - Quickly adjusts to maintain BP

Integrated Control Mechanisms

- Respiratory Effects
  - Respiratory Sinus Arrhythmia (RSA)
    - This arrhythmia is not a bad thing!
  - HR acceleration linked to inspiration
  - HR deceleration linked to expiration
- RSA
  - Indexes strength of Vagal influence
  - More later…

Cardiac Inotropy

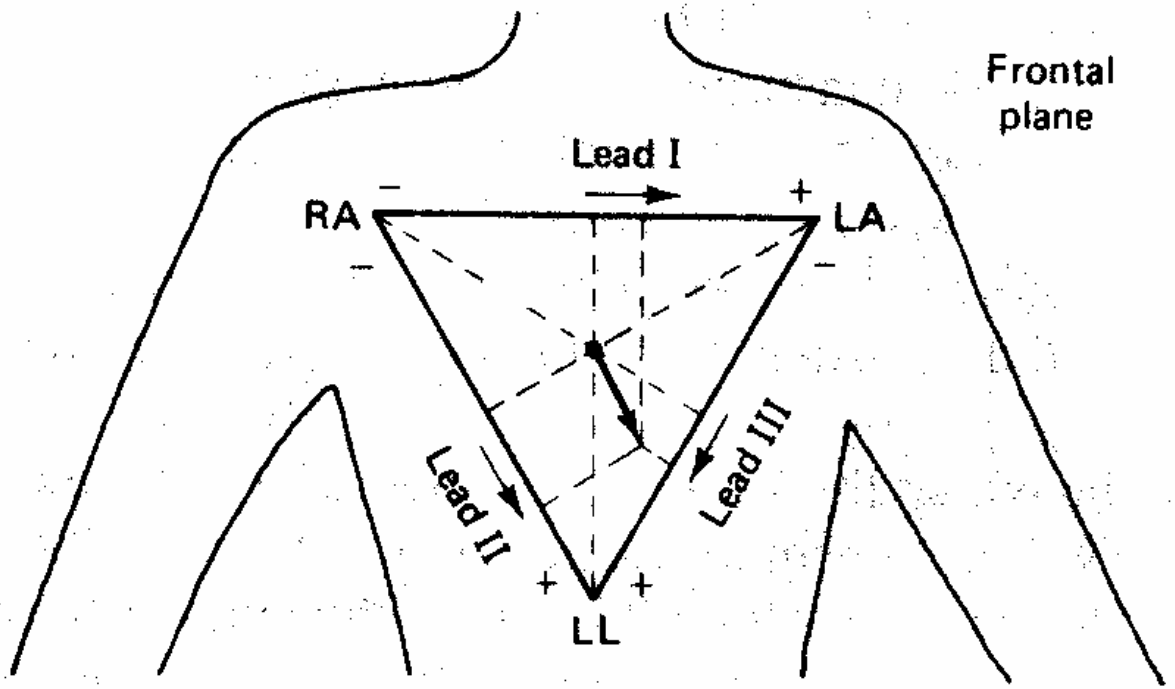
- Contractility is predominately Sympathetically mediated
- Often measured invasively, but can be measured noninvasively
  - EKG plus phonocardiogram
  - Impedance cardiography

Cardiovascular Measures

- Electrocardiogram (EKG)
- Phonocardiogram (PCG)
- Impedance cardiography
- Photoplethysmography
- Ballistocardiography
- Blood Pressure

EKG

AC signal
Sample 200-500 Hz

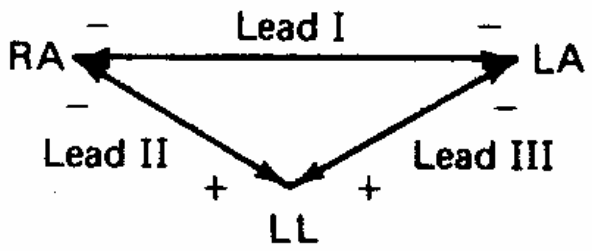


Bipolar

Bipolar limb leads: ECG voltage measurements between pairs of limbs:

Lead I:	between RA and LA
Lead II:	between RA and LL
Lead III:	between LA and LL

Einthoven triangle, showing relation of the bipolar limb leads



Which Time?

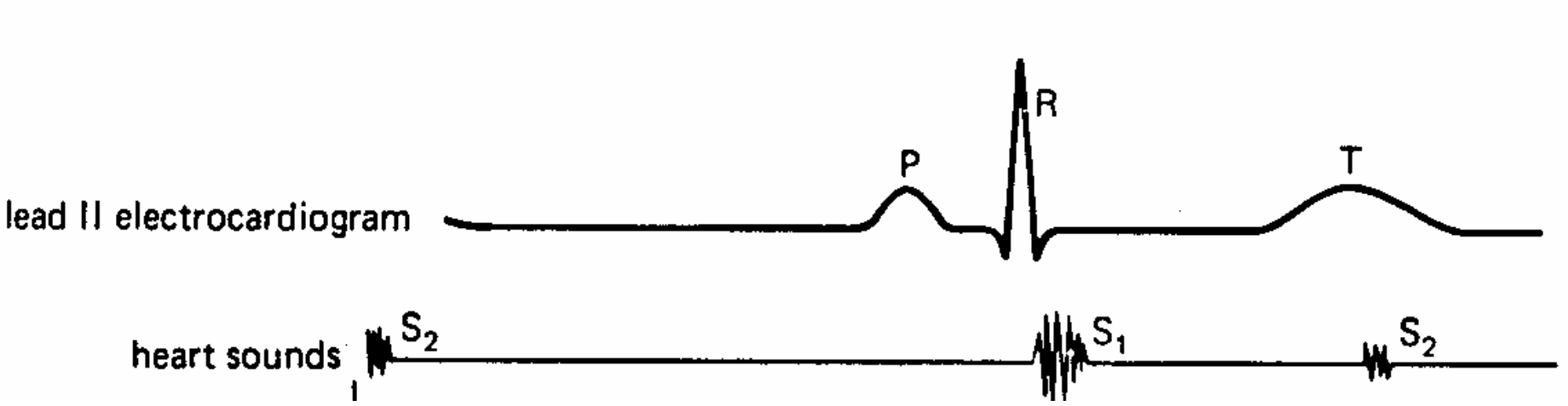
- Real time
  - Heart Rate
  - Expressed as beats per time (usually bpm)
- Cardiac time
  - Heart Period; interbeat interval (IBI)
  - Expressed in msec
- Converting

$$HR = \frac{1}{HP} x 60{,}000$$

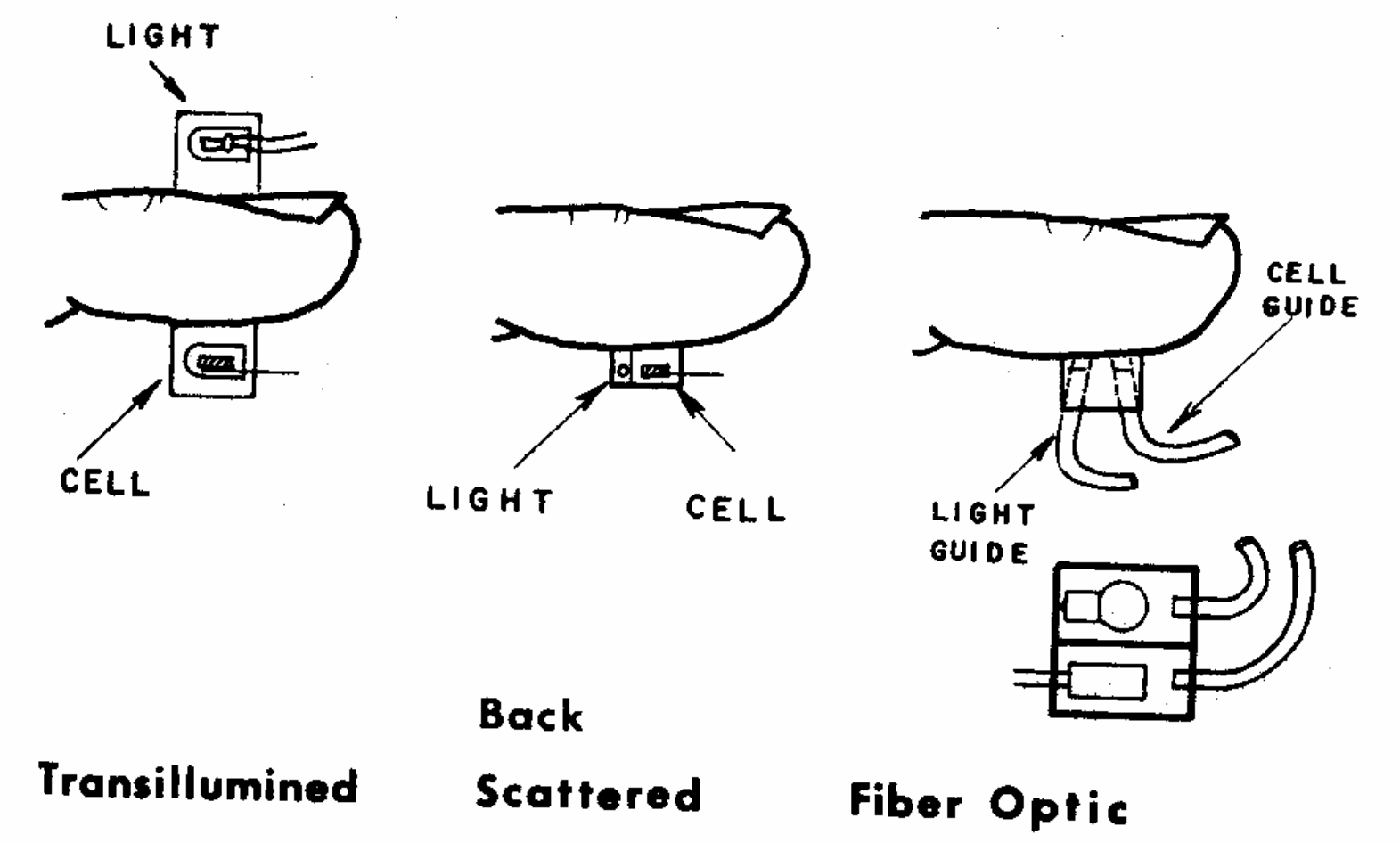
$$HR = \frac{1}{1000} X 60{,}000 = 60 bpm$$

Phonocardiography

- Position microphone over heart
- Lub-Dub is transduced to electrical signal

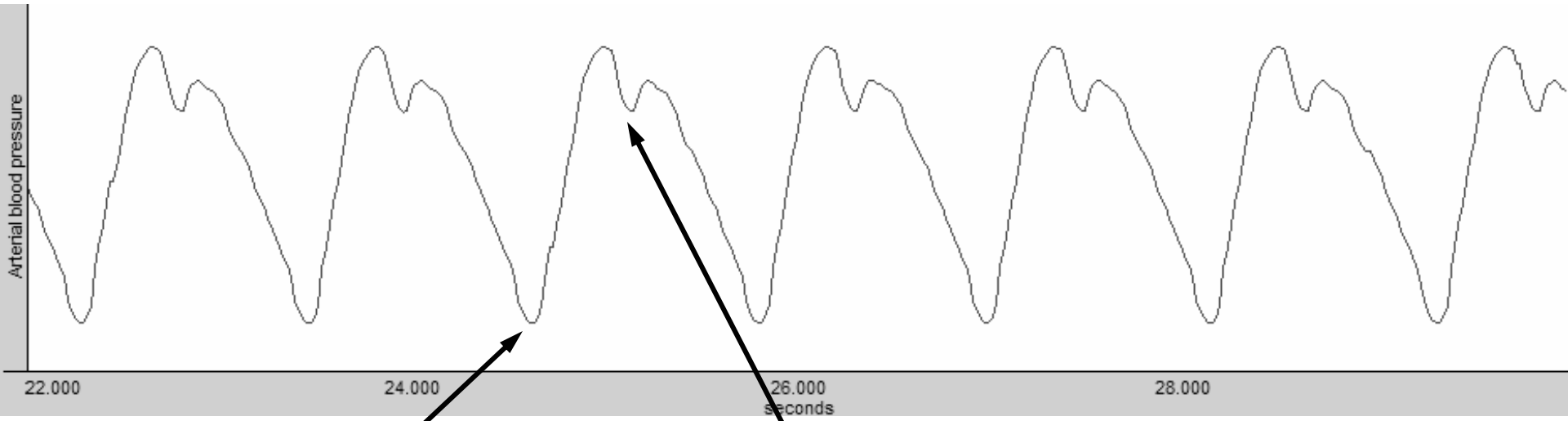


Photoplethysmography



Three methods, all involve measuring light absorbed by peripheral vasulature

The Photoplethysmographic Output

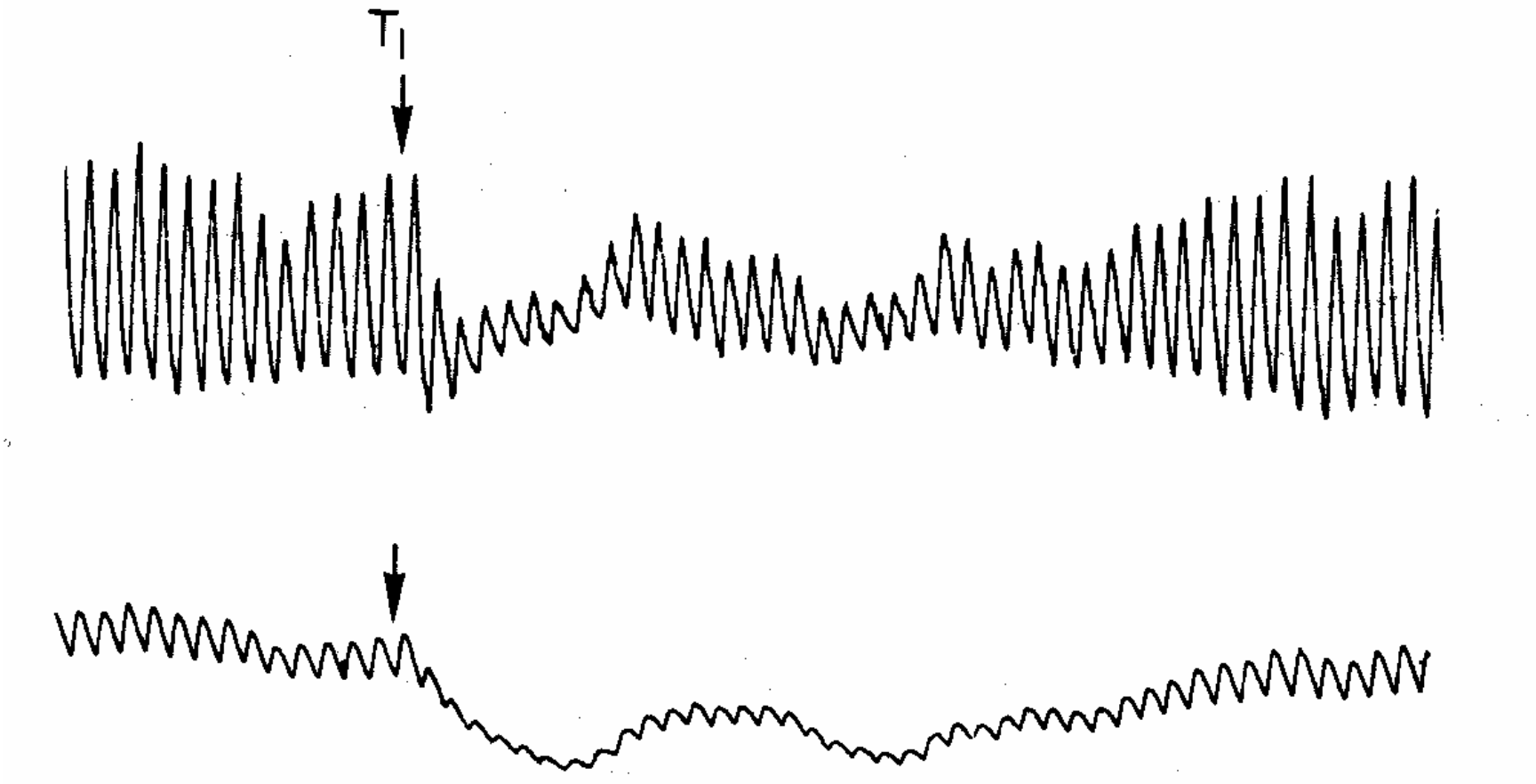


~LVET

Increase in Pressure due to opening of Aortic Valve

Dichrotic Notch; closing of valve, end of ejection

Photoplethysmograph: Peripheral Vasoconstriction

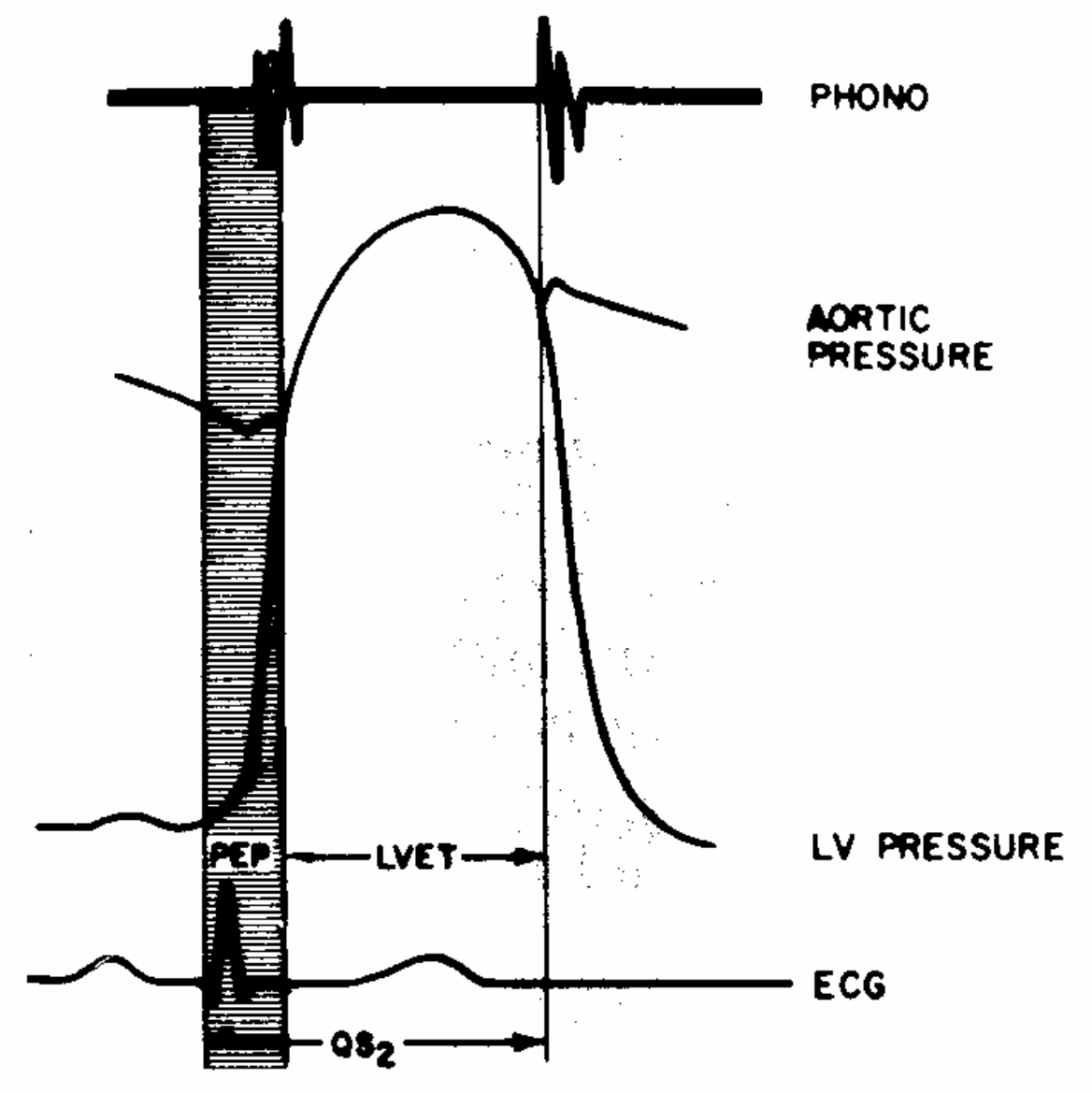


T1 is onset of constriction
Top Panel: Pulse Volume (recorded with 1 sec time constant)
Lower Panel: Blood Volume (no filter)

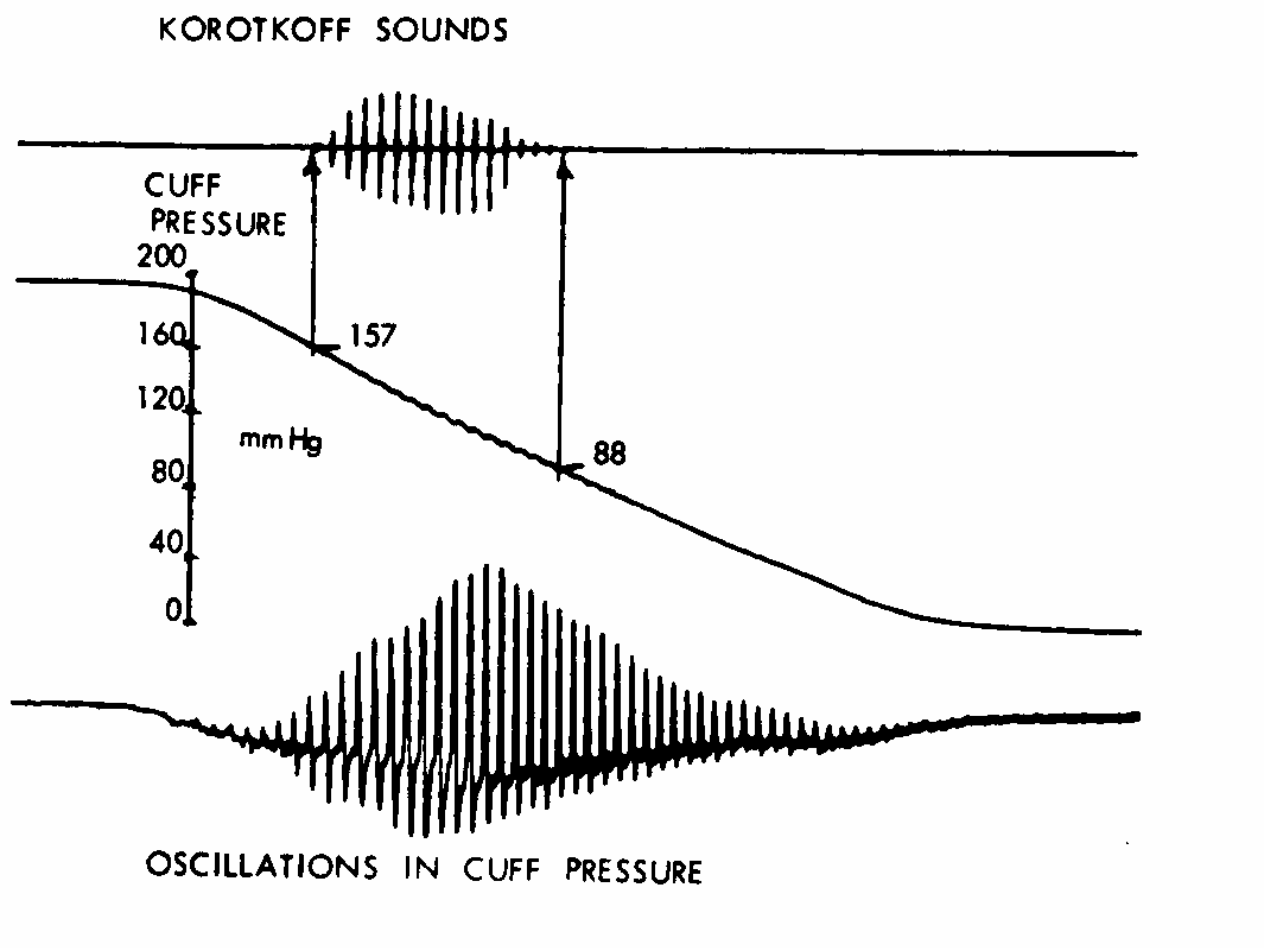
Measuring contractility with EKG, PCG, and Photoplethysmography

PEP = Pre-ejection period
LVET = Left Ventricular Ejection Time
= Upswing of pressure wave to S2
Electromechanical Systole = Q to S2
PEP = EMS – LVET

PEP reflects sympathetic influence on cardiac contractility



Measuring Blood Pressure



Auscultatory Technique

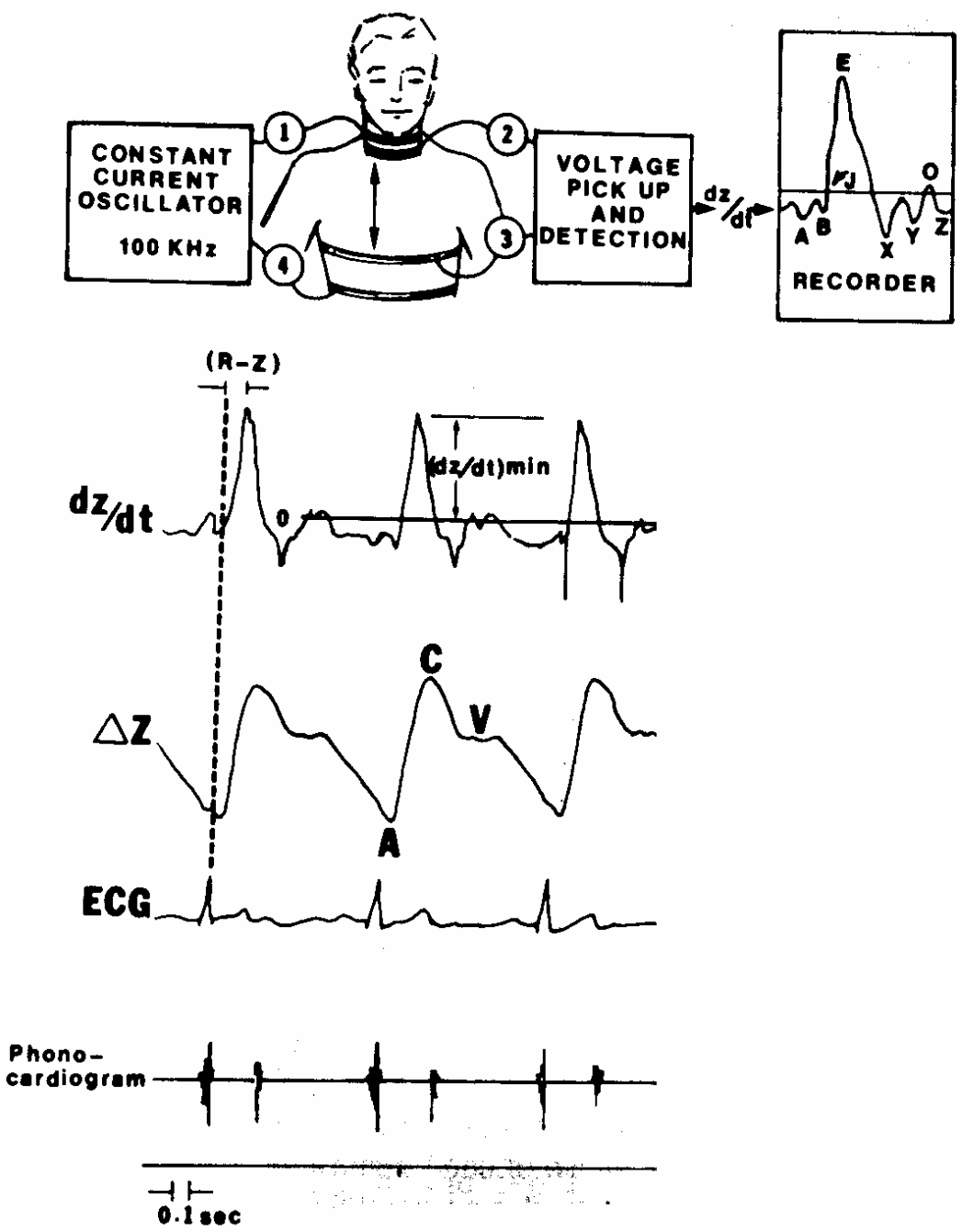
- Not good for instantaneous readings
- Not good for repeated readings

Ballistocardiography

- Imagine
  - On a chair on a platform on an air hockey table
  - Cardiac events cause movement of platform
- New applications:
  - Finding individuals hiding in vehicles
  - Finding individuals stuck in rubble

Impedance Cardiography

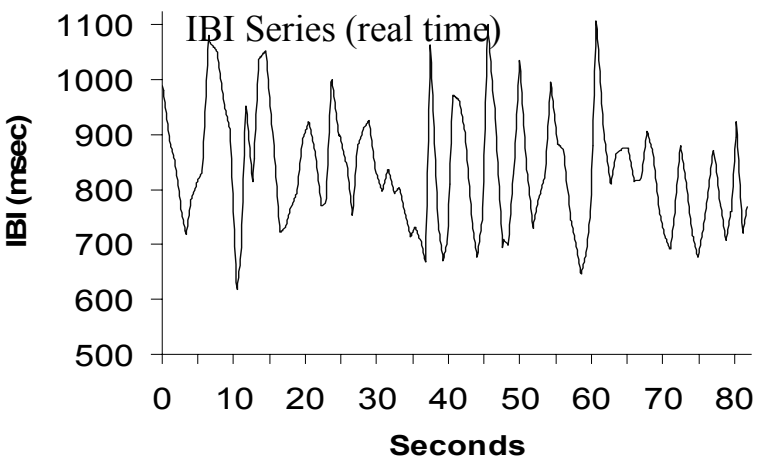
- Low energy high-frequency AC passed through thoracic region
- Changes in impedance to signal created by mechanical events of cardiac cycle, especially changes in thoracic blood volume
- ΔZ is change in impedance
- Dz/dt is 1st derivative of impedance signal Z
- R-Z is time from r-wave to peak ventricular contraction indicated in Z signal
- The "Heather" index – divide dz/dt by R-Z interval; putative measure of heart's ability to respond to stress



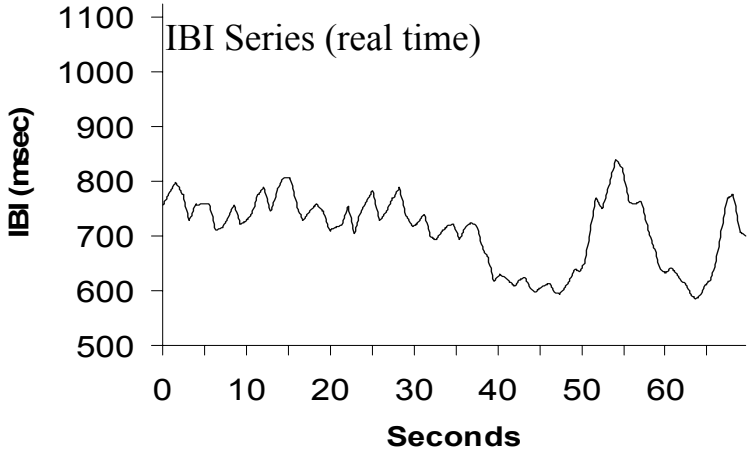
Measuring Vagal Influence

- Descending Vagal Influence slows HR
- Respiration interrupts this vagal influence
- The size of periodic oscillations due to respiration will therefore index the strength of the Vagal influence
- Demo

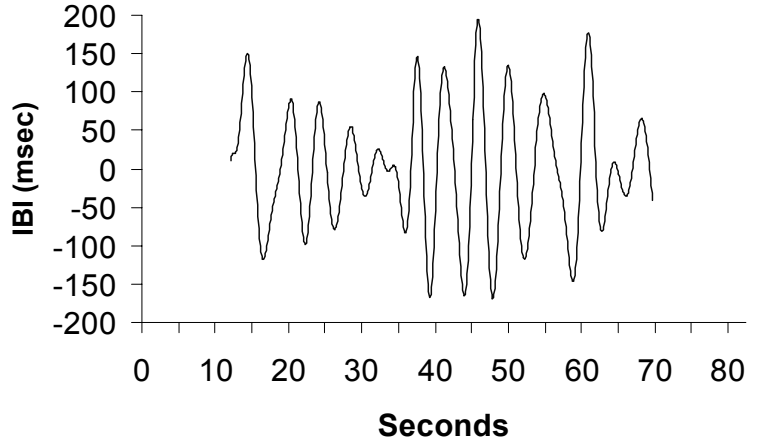
High Variability Subject



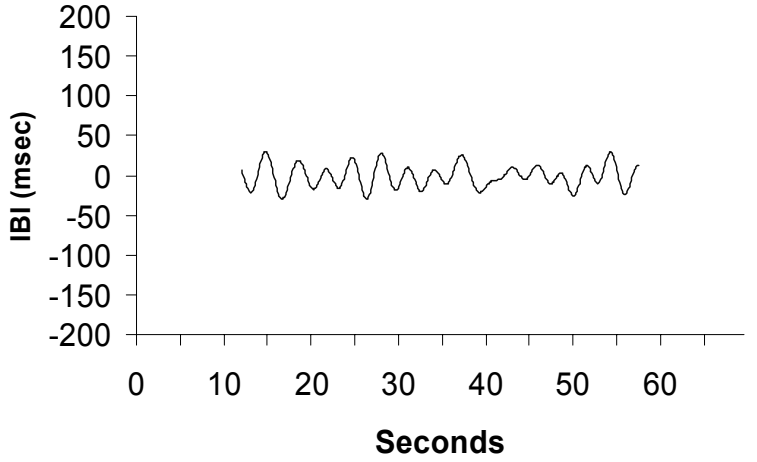
Low Variability Subject



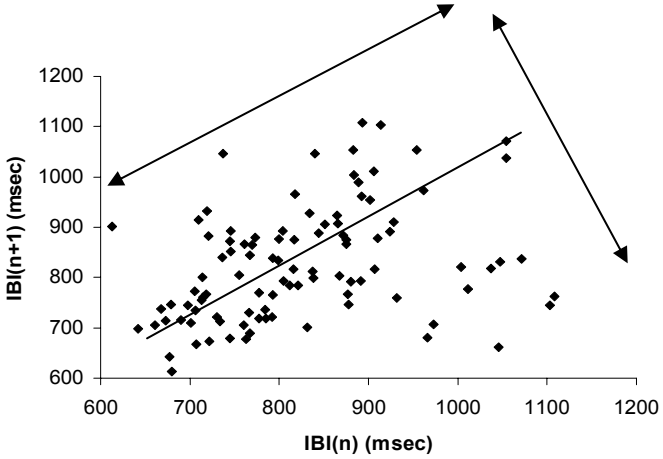
.12-.40 Hz filtered IBI Time Series



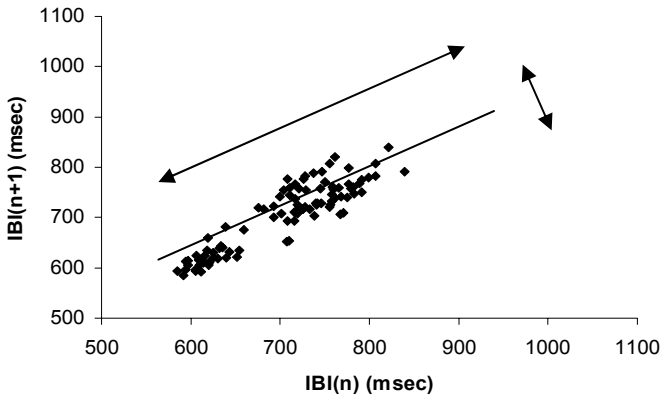
.12-.40 Hz filtered IBI Time Series



High Variability Subject



Low Variability Subject



Rate		
73.3	HR	85.7
832.3	IBI	707.7
Total Variability		
9.2	HRV	8.3
112.4	SDNN	66.3
132.8	RMSSD	27.7
"Sympathetic"		
1.4	CSI	4.7
"Parasympathetic"		
57.1	PNN50	10.8
97.6	MCD	22.0
5.3	CVI	4.5
8.8	RSA	5.3

Vagal Tone and Modulation

- Two Vagal Efferent Branches which terminate on SA Node
  - Reptilian “Dumb”: Dorsal Motor Nucleus
    - Massive reduction in HR & conservation of oxygen.
    - Dive reflex
  - Phylogentically newer “smart” Vagus
    - Orginates from Nucleus Ambiguous
    - Modualtes influence to:
      - Promote attentional engagement, emotional expression, and communication.
    - Mobilizes organism to respond to environmental demands
      - Phasicly withdraws inhibitory influence, increasing HR
      - Upon removal of the environmental stressor, resumes its efferent signal
        - Slowing heart rate
        - Allows the organism to self-sooth

Porges 1995, Beauchaine, 2001

Table 1
The three phylogenetic stages of the neural control of the heart proposed by the Polyvagal Theory

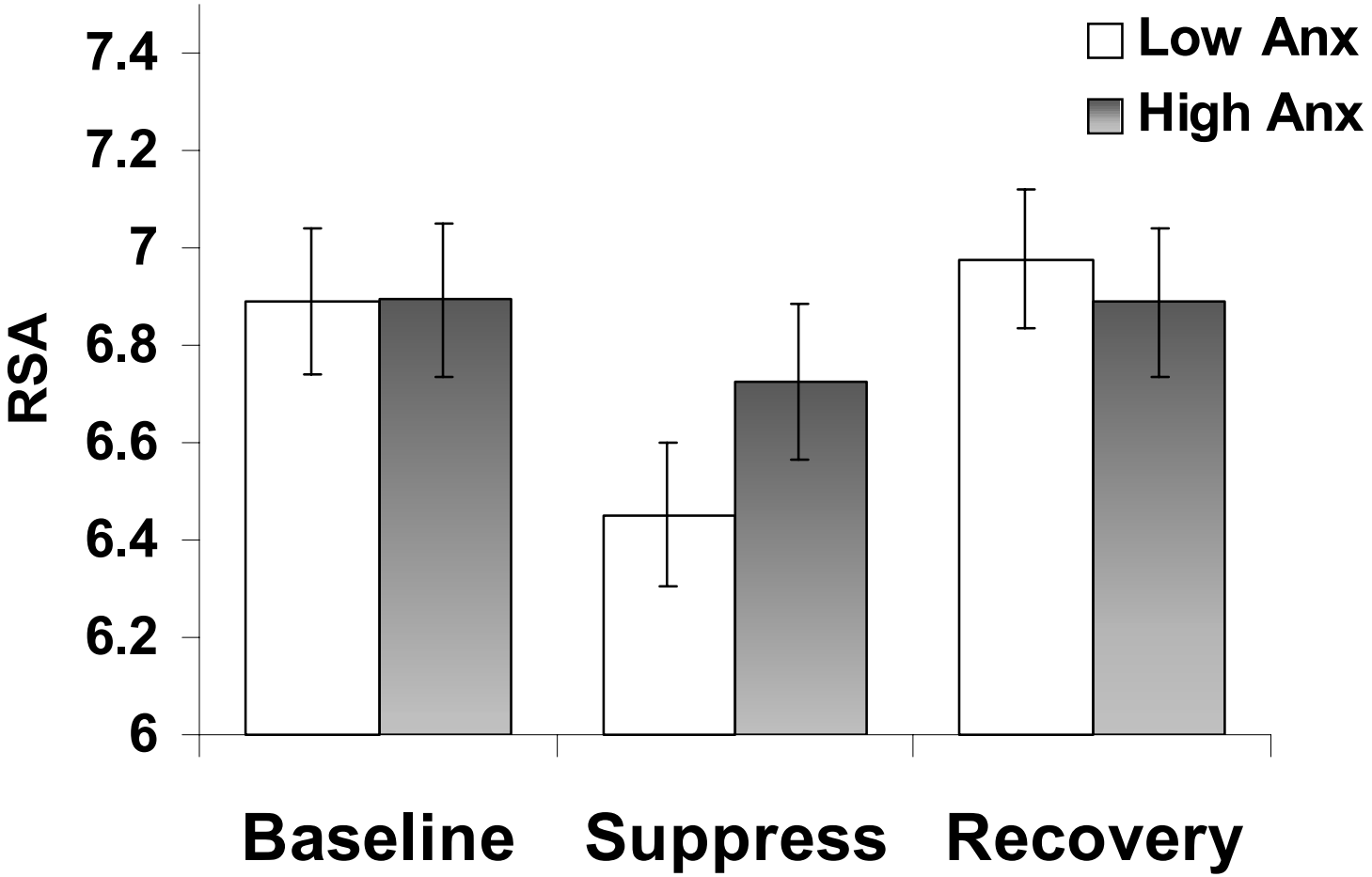
Phylogenetic stage	Autonomic nervous system component	Behavioral function	Lower motor neurons
III	Myelinated vagus	Social communication, self-soothing and calming inhibit sympathetic-adrenal influences	Nucleus ambiguus
II	Sympathetic-adrenal	Mobilization (active avoidance)	Spinal cord
I	Unmyelinated vagus	Immobilization (death feigning and passive avoidance)	Dorsal motor nucleus of the vagus

Porges, 2003

Tonic Vs Phasic

- Tonic Level indexes capacity
- Phasic change indexes actualization of that capacity
- Attention
  - higher vagal tone was associated with faster reaction time to a task requiring sustained attention
  - Hyperactive kids treated with Ritalin (Porges, Walter, Korb, & Sprague, 1975).
    - attentional skills improved
    - appropriate task-related suppression of heart rate variability was observed while performing the task requiring sustained attention
- Emotion
  - Beauchaine (2001):
    - low baseline vagal tone is related to negative emotional traits
    - high vagal withdrawal is related to negative emotional states

Task-related and Emotion-related modulation



Movius & Allen, 2001

Trait Vagal Tone

- Infants
  - Various sick infants have lower vagal tone (Respiratory Distress Syndrome, Hydrocephalic)
  - Infants with higher vagal tone (Porges, various years)
    - More emotionally reactive (both + & -)
    - More responsive to environmental stimuli (behaviorally and physiologically)
- Anxiety Disorders
  - Lower Vagal Tone in GAD (Thayer et al., 1996)
  - Lower Vagal Tone in Panic Disorder (Friedman & Thayer, 1998)
- Depression
  - Depression characterized by lower Vagal tone?
  - Gender may moderate (Thayer et al., 1998)
    - Note small sample: 15 depressed, 11 controls
  - State dependent? (Chambers & Allen, in press)

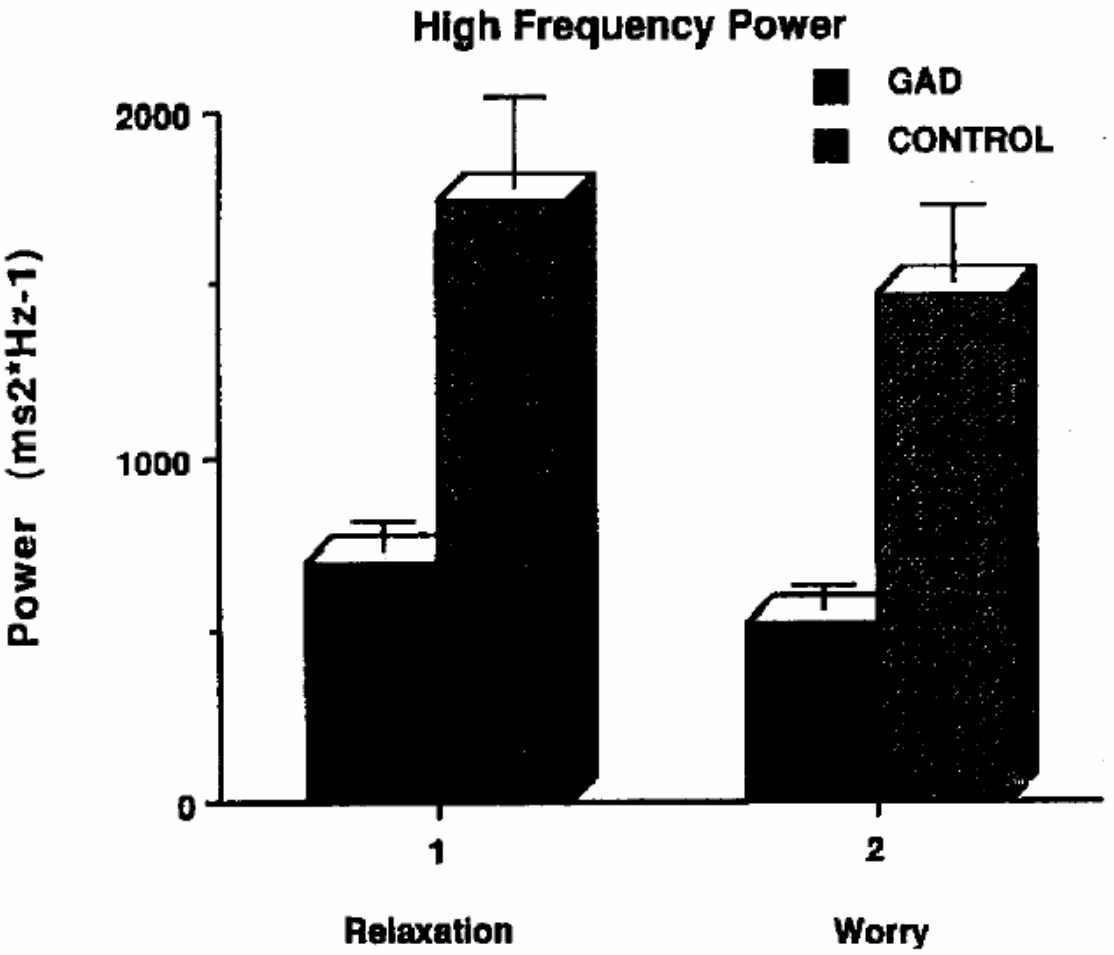
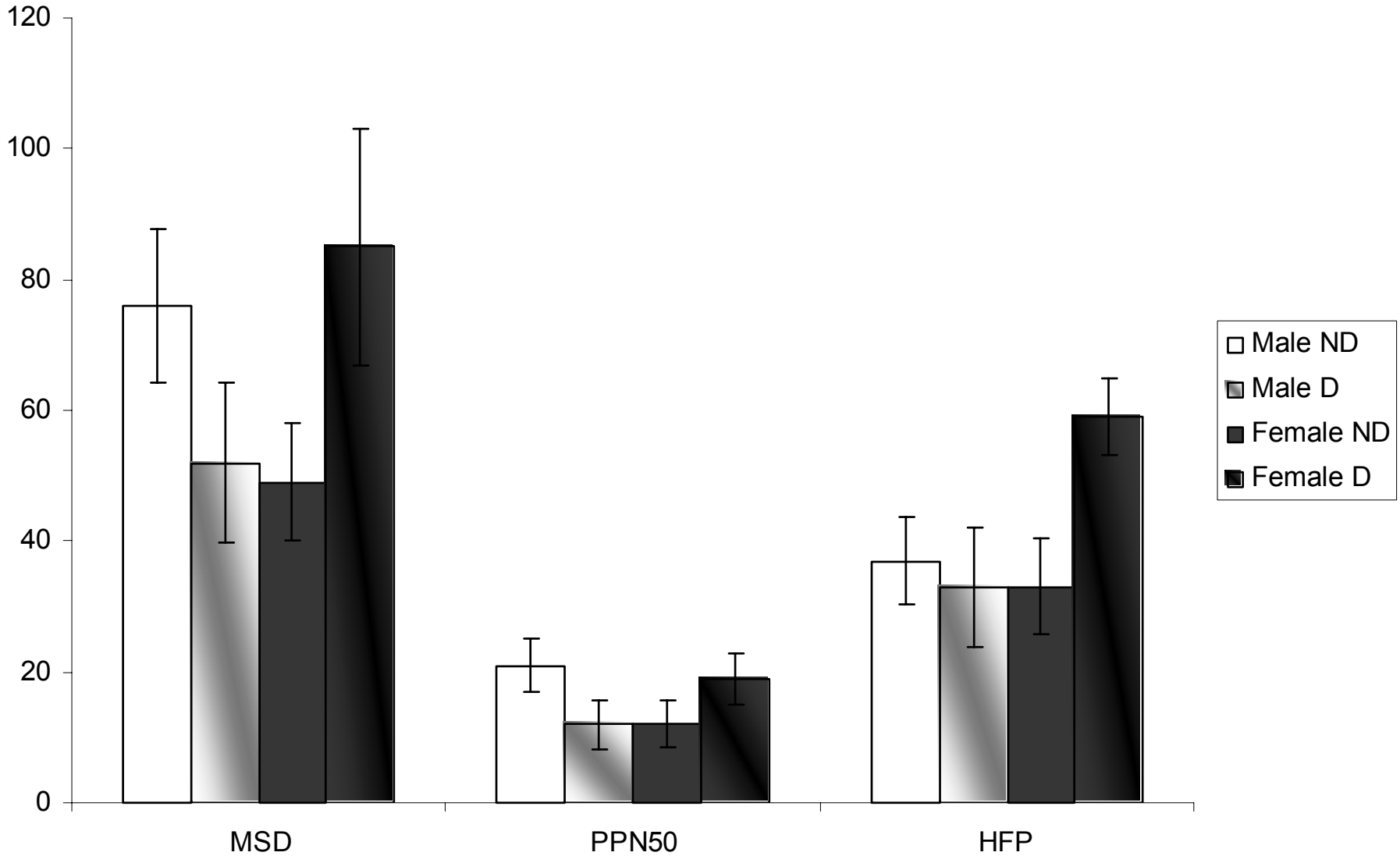


Figure 1. Power in the high frequency (respiratory) component of heart period variability in GAD patients and controls during relaxation and worry.

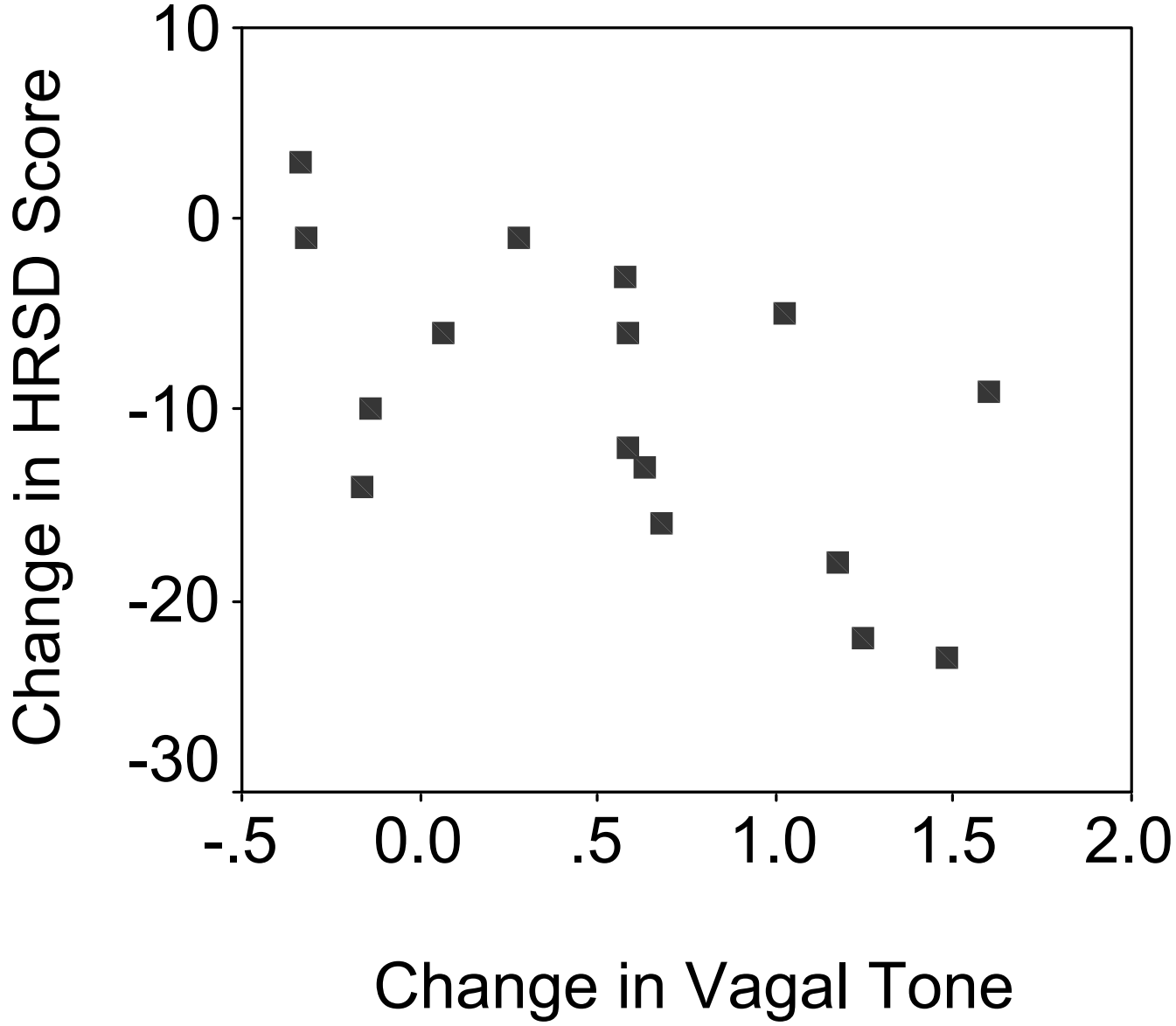
Table 1
Significant contrasts among panickers, blood phobics, and controls

Variable	Panic (mean, S.D.)	Blood phobic (mean, S.D.)	Control (mean, S.D.)	T ratio, df, p value
IBI (ms)	761.8 (141.0)	837.1 (92.4)	905.2 (132.5)	P < B 4.59 (215) $p<0.001$ P < C 7.65 (214) $p<0.001$ B < C 4.30 (207) $p<0.001$
VAR (ms^2)	3942 (4009)	4334 (2663)	6112 (4563)	P < C 3.70 (214) $p<0.001$ B < C 3.44 (207) $p<0.001$ P = B N.S.
MSD (ms)	44.4 (31.2)	55.6 (22.7)	71.4 (32.1)	P < B 3.05 (215) $p<0.001$ P < C 6.34 (214) $p<0.001$ B < C 4.11 (207) $p<0.001$
HF power (ms^2 Hz^{-1})	991 (1225)	1385 (1073)	2239 (1911)	P < B 2.49 (212) $p<0.01$ P < C 5.67 (212) $p<0.001$ B < C 3.90 (203) $p<0.001$
LF/HF	2.1(2.5)	1.3 (1.8)	1.0 (1.5)	P < B 2.41 (209) $p<0.005$ P < C 3.64 (203) $p<0.001$ B = C N.S.

P, panic; B, blood phobic; C, control.



Data from Thayer et al., 1998, *Bio Psychiatry*



Chambers and Allen (2002) *Psychophysiology*

Trait Vagal Tone (cont')

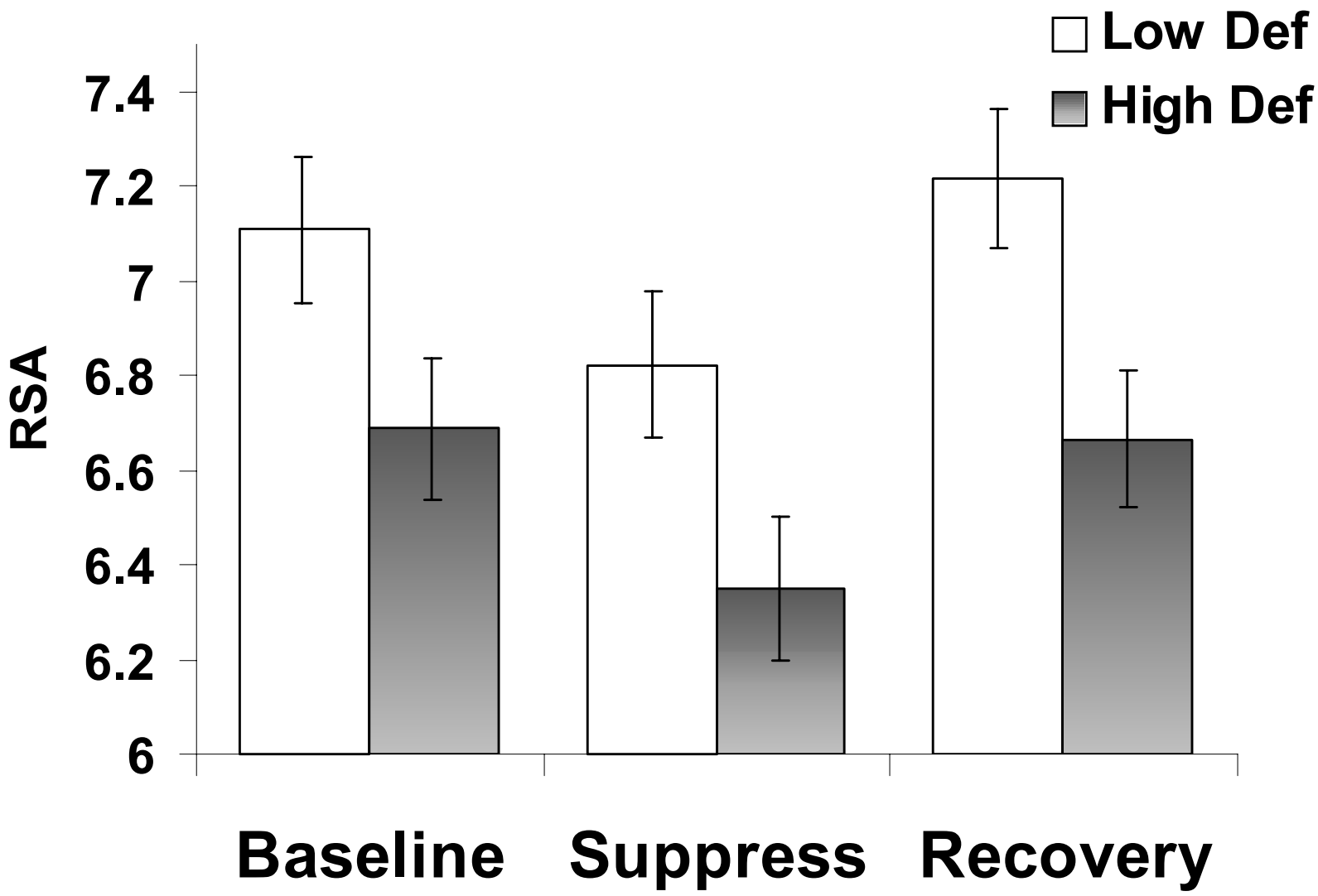
- Defensive Coping (Movius & Allen, 2001)
- Integrative Developmental Model

Beauchaine (2001)

Table 1. *Patterns of autonomic nervous system functioning in common psychopathologies and personality types*

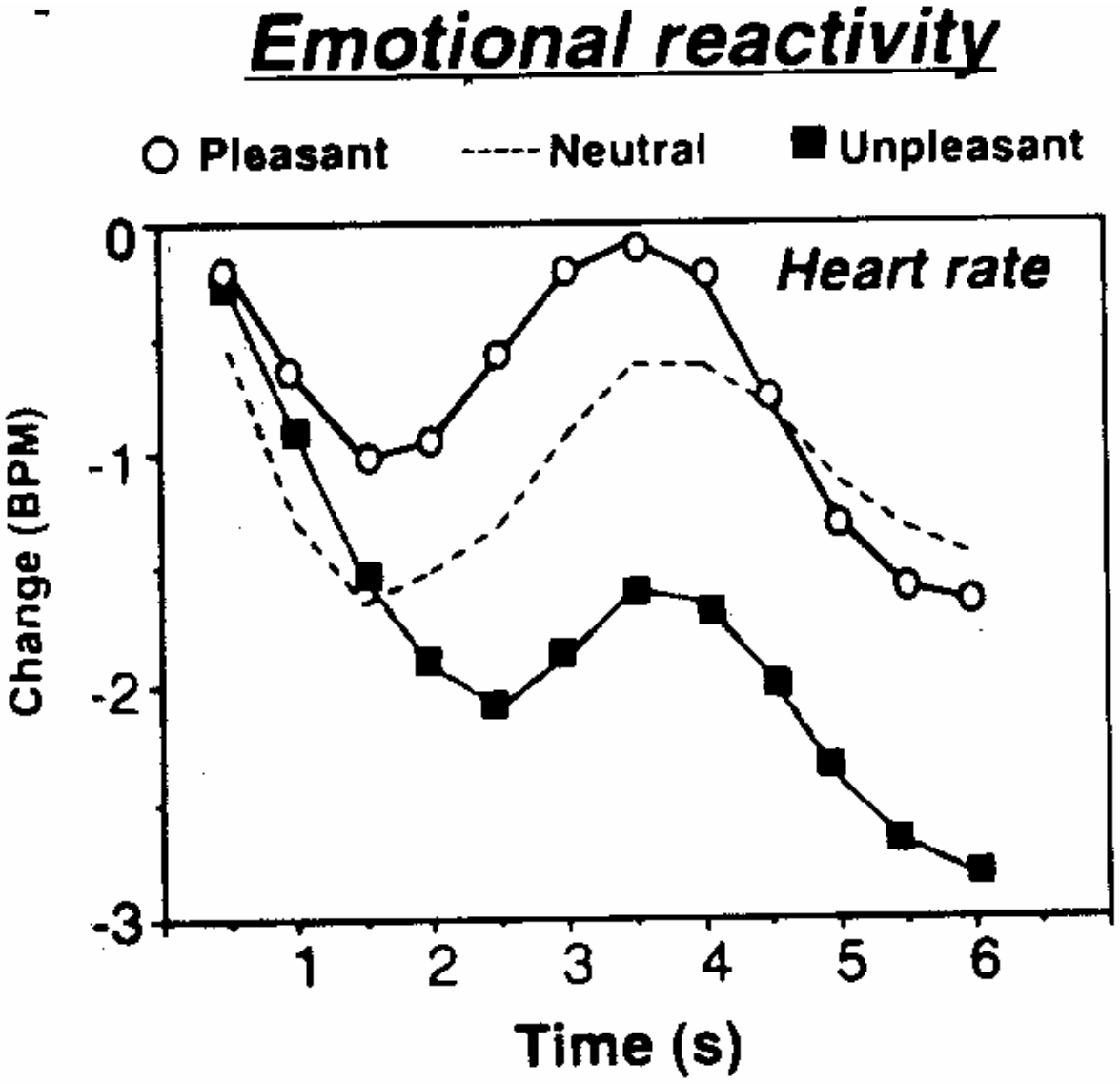
Motivational Predisposition	Behavioral Manifestation	Motivational System (SNS)		Regulational System (PNS)	
		Activation (BAS)	Inhibition (BIS)	Emotional Trait (RSA)	Emotional State (RSA Reactivity)
Disinhibition	Impulsivity (ADHD)	High	Low	—	—
	Aggression (UACD)	High	Low	Low	High
	Panic	High	High	Low	High
	Extraversion	High	—	—	—
Inhibition	Anxiety	—	High	Low	—
	Depression	Low	High	Low	—
	Panic	High	High	Low	High
	Introversion	—	High	—	—
None	Emotional stability	—	—	High	—
	Emotional lability	—	—	—	High

Note: High, atypically high activity; Low, atypically low activity. Dashes represent normal activity. Entries in the BIS, RSA, and RSA reactivity columns are supported by the literature reviewed herein. Entries in the BAS column are more speculative and require empirical confirmation.

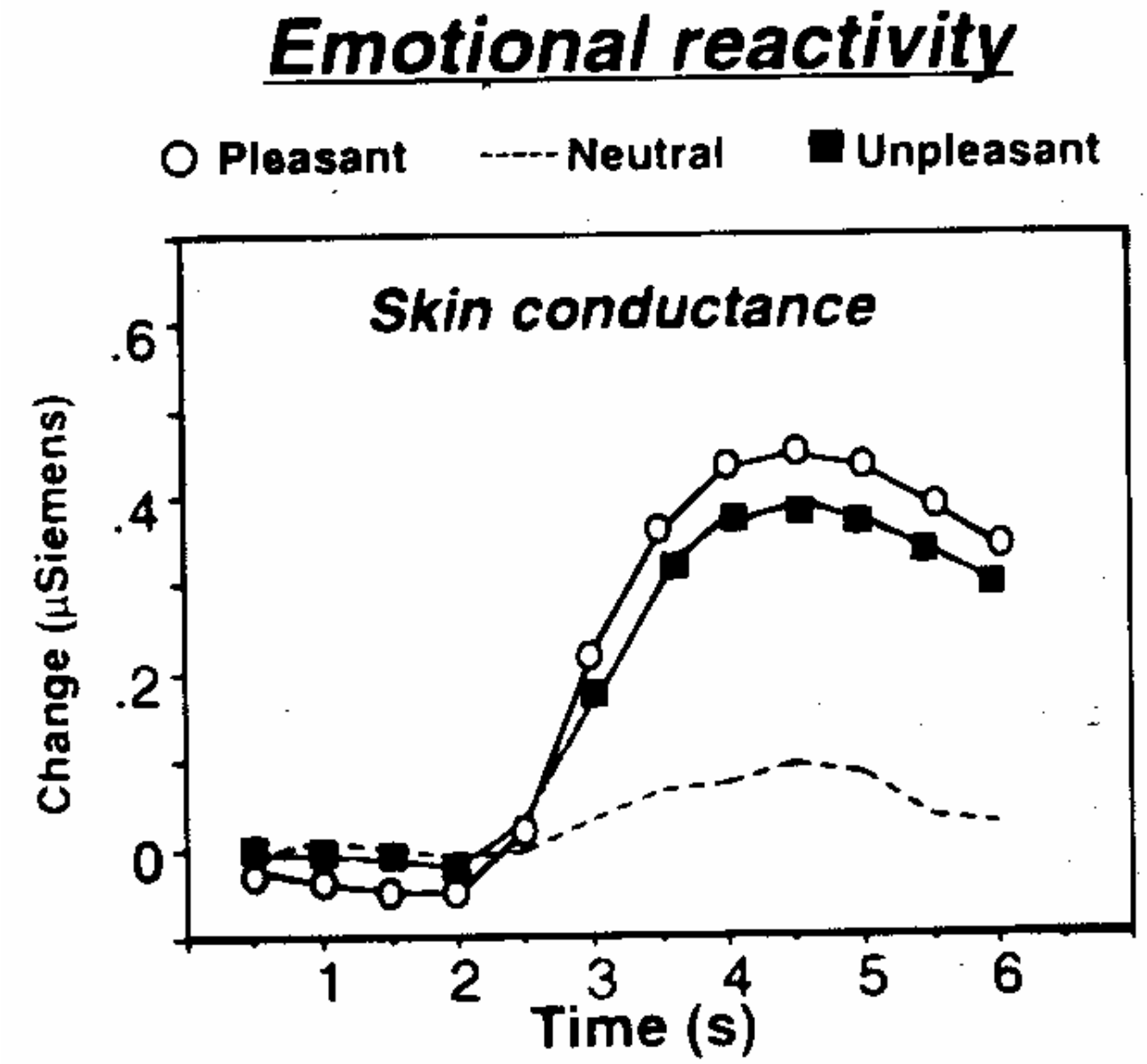


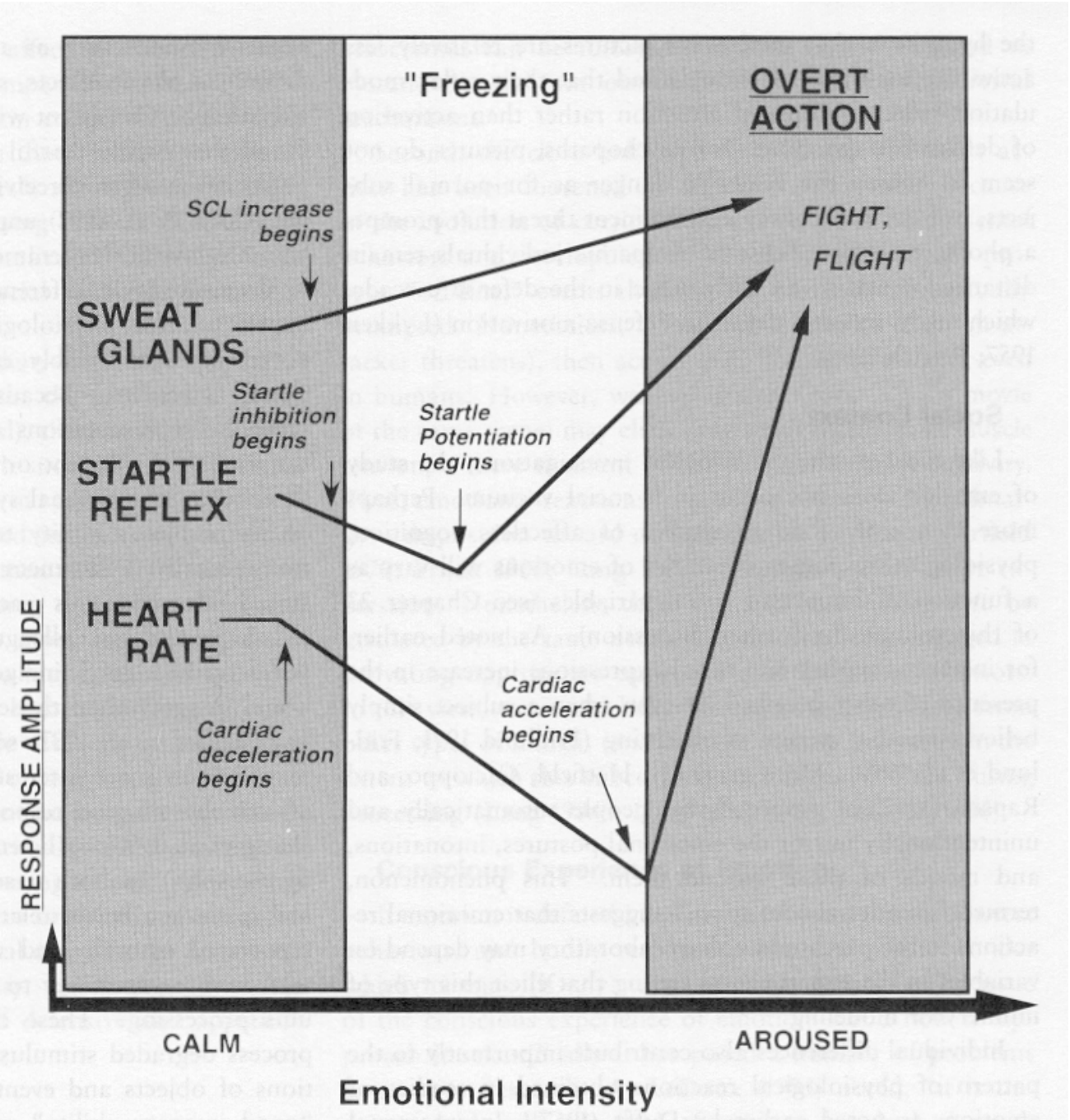
Movius & Allen, 2001

Orienting, Attention, and Defense



SCR (by contrast)




"Freezing"
OVERT ACTION
SCL increase begins
FIGHT, FLIGHT
SWEAT GLANDS
Startle inhibition begins
Startle Potentiation begins
STARTLE REFLEX
HEART RATE
Cardiac deceleration begins
Cardiac acceleration begins
RESPONSE AMPLITUDE
CALM
AROUSED
Emotional Intensity

OR Vs DR