ELEC ENG 3BB3:

Cellular Bioelectricity

Notes for Lecture 29B

Thursday, March 27, 2014

Clinical applications:

Because of the problems involved with spatial selectivity and recruitment, FES has been most successful in clinical applications where these two issues are not so crucial, for example:

- cardiac pacemakers, cochlear implants, bladder control, respiratory control, gross motor movements, deep brain stimulation

More challenging for clinical application are:

- fine motor control, retinal implants, etc.

Clinical applications (cont.):

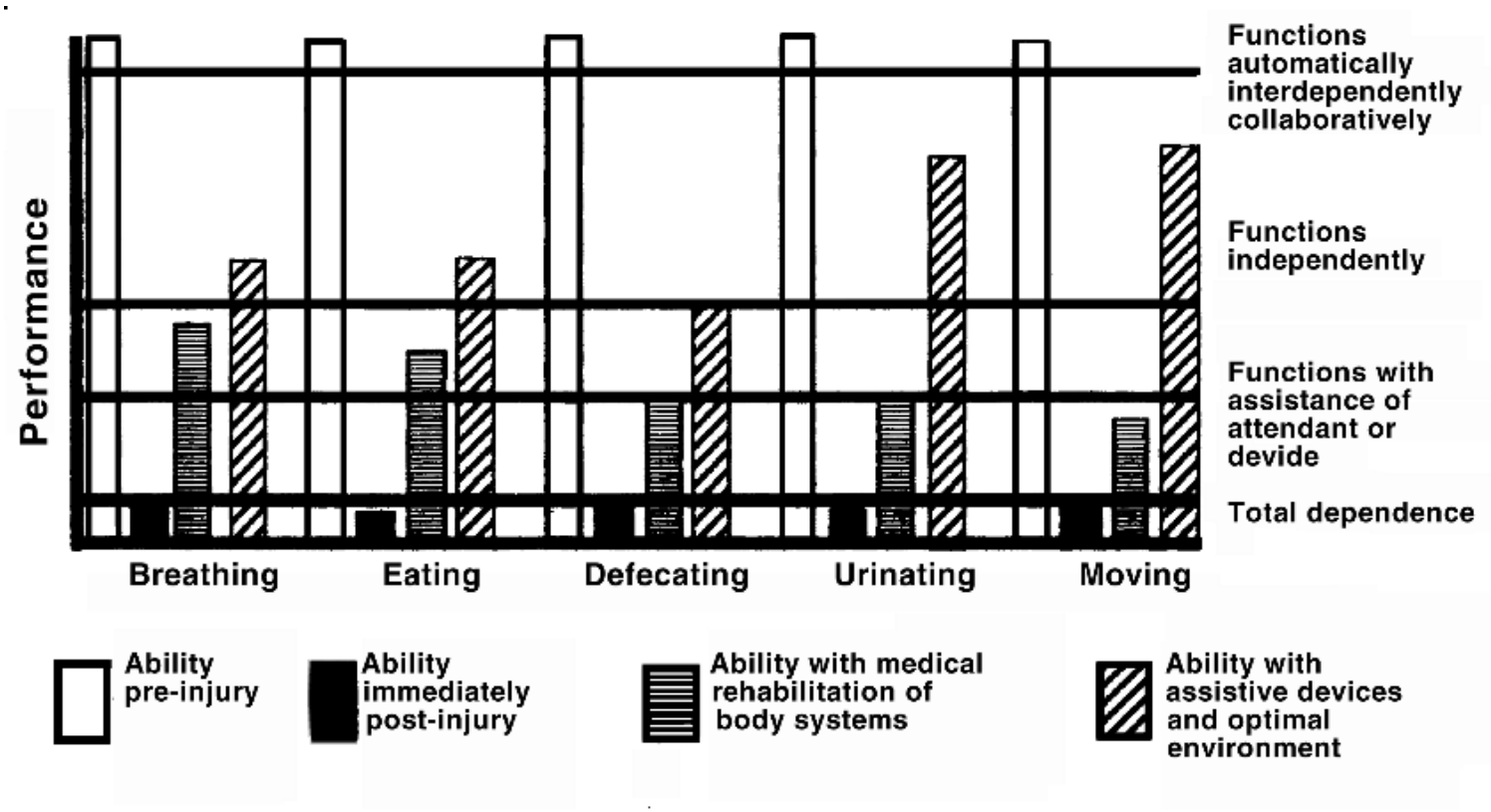


Figure 12.26. Potential Optimal Effects of Medical Rehabilitation and the use of assistive technologies in improving the lives of people with disabilities. Pekham PH, Gray DB. 1996. Functional neuromuscular stimulation (FNS). *J Rehab Res Dev* **33**(2):ix–xi.

Pacemakers:

- First major application of electrical stimulation of excitable cells
- Stimulate just ventricles, or atria and ventricles (dual-chamber)
- Typically platinum or platinum-iridium electrodes, monopolar or bipolar
- Monophasic or biphasic waveforms used
- Both cathode make excitation and anode break excitation are likely to occur

Pacemakers (cont.):

(Guyton and Hall, 2001)

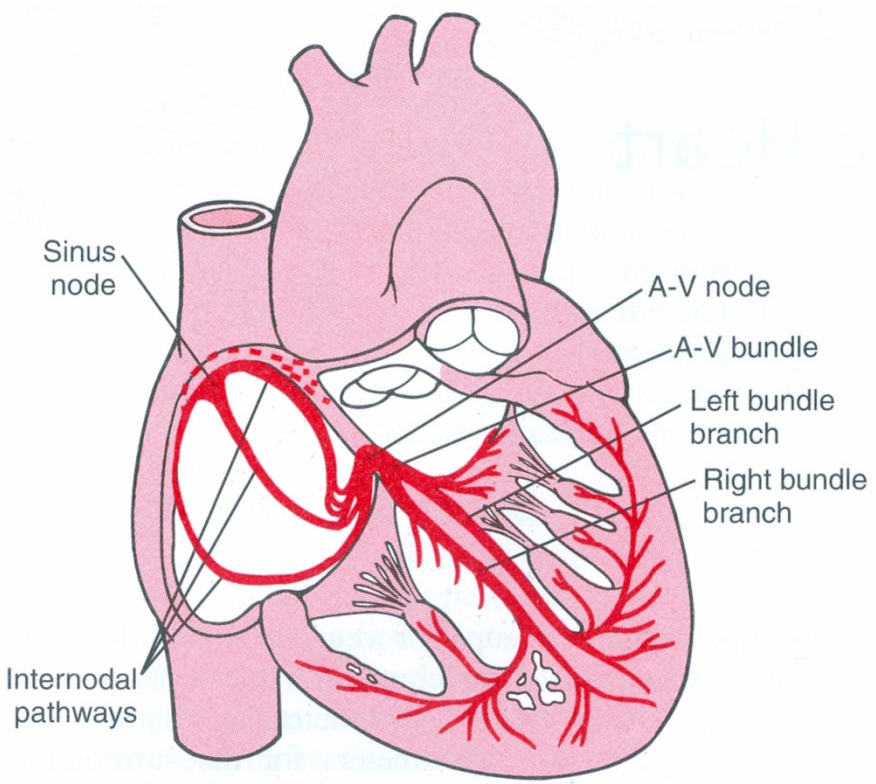


FIGURE 10–1

Sinus node and the Purkinje system of the heart, showing also the A-V node, atrial internodal pathways, and ventricular bundle branches.

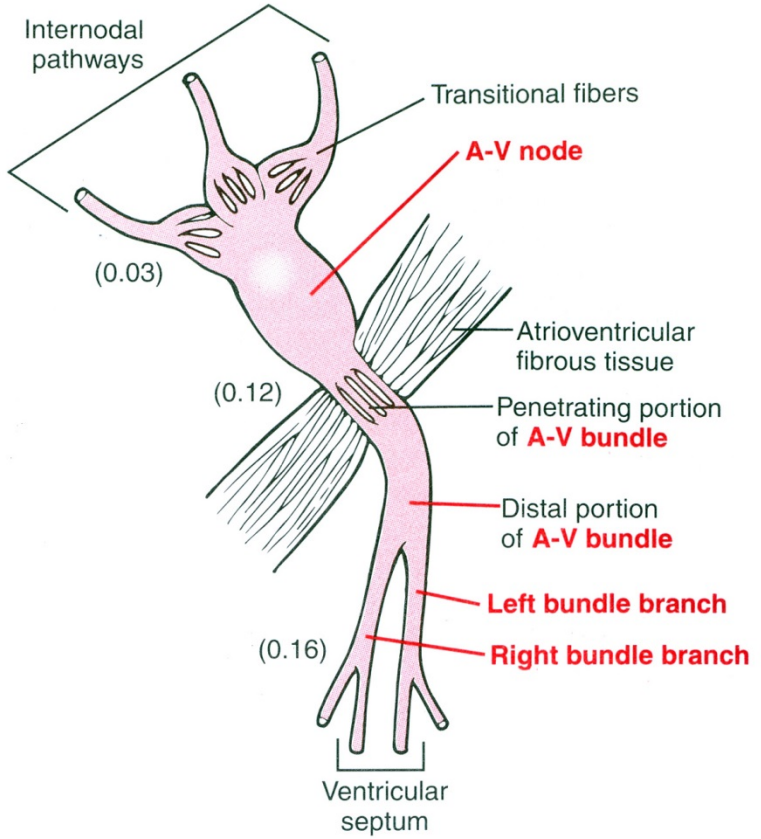
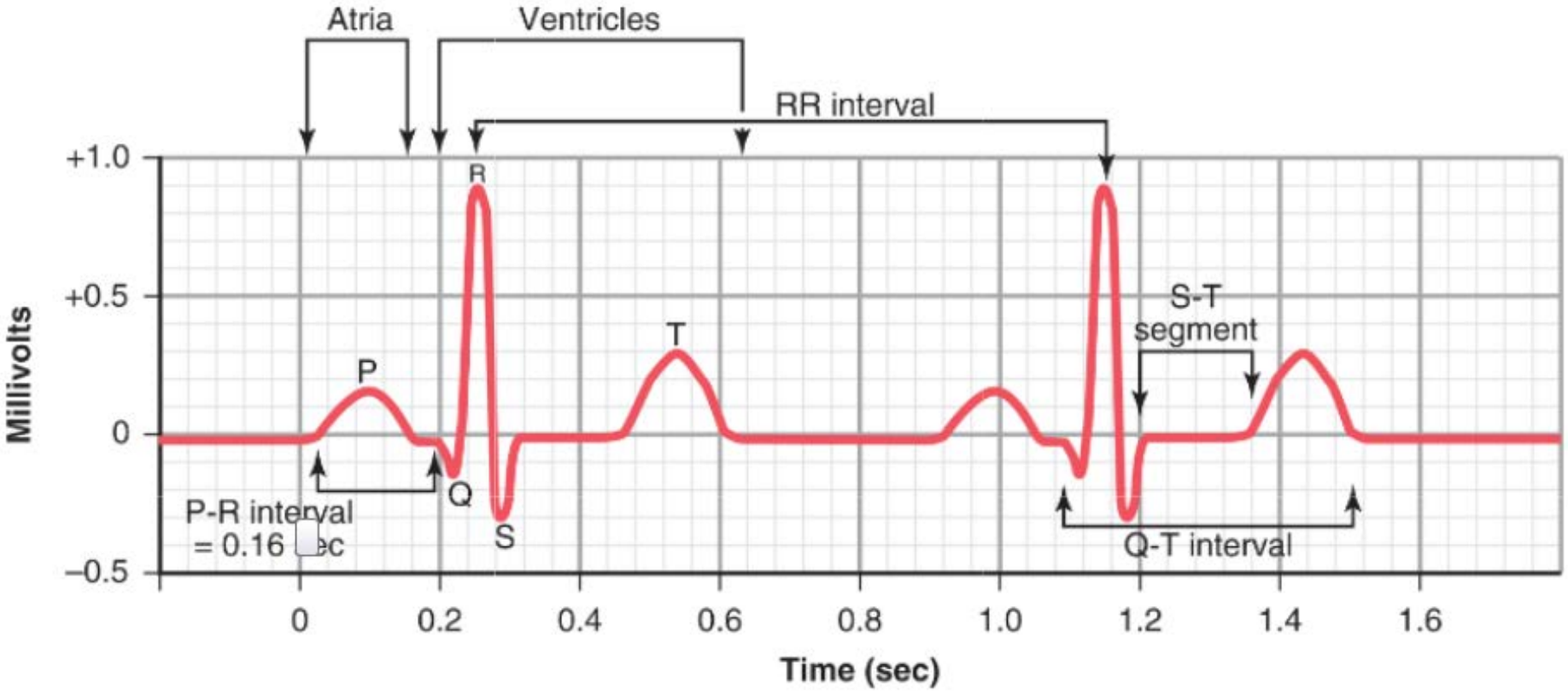


FIGURE 10–3

Organization of the A-V node. The numbers represent the interval of time from the origin of the impulse in the sinus node. The values have been extrapolated to humans.

ECG Interpretation 101:

(Guyton and Hall, 2001)



ECG Interpretation 101:

(Guyton and Hall, 2001)

FIGURE 13–1

ECG Interpretation 101 (cont.):

(Guyton and Hall, 2001)

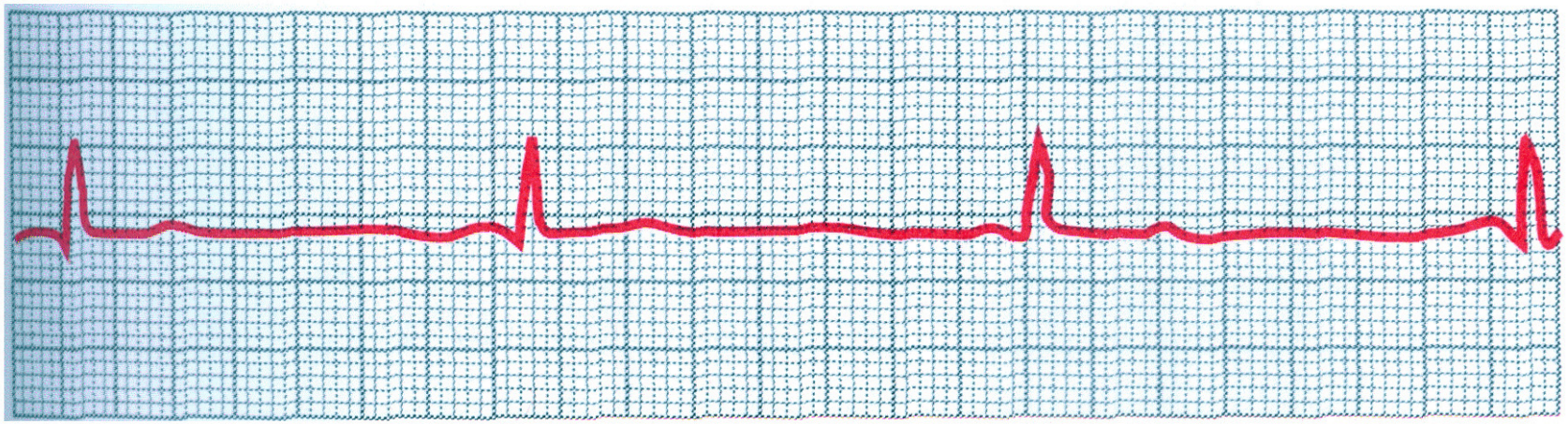


FIGURE 13–2

ECG Interpretation 101 (cont.):

(Guyton and Hall, 2001)

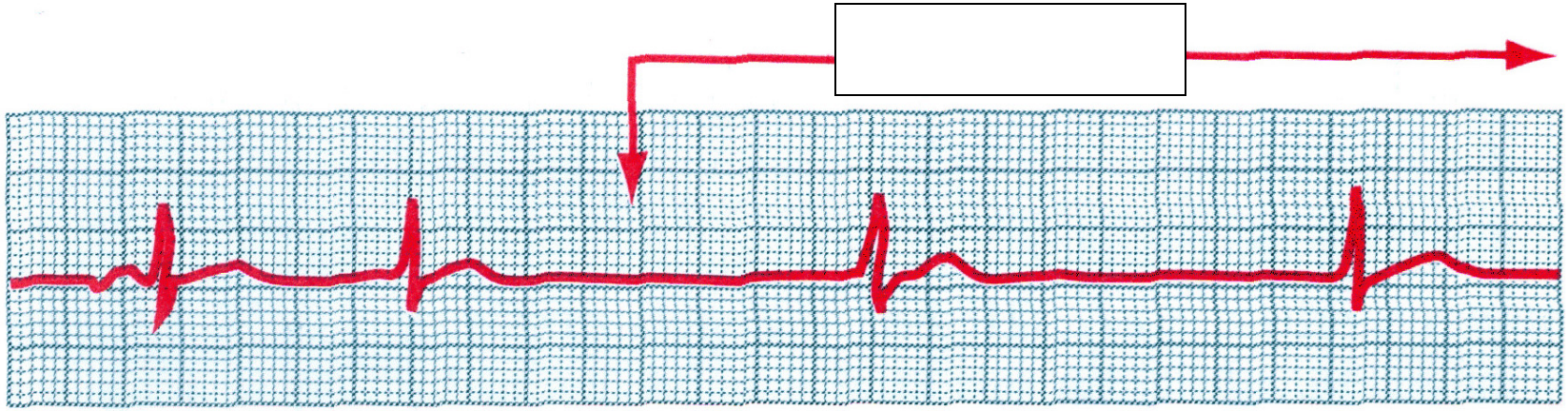


FIGURE 13–4

ECG Interpretation 101 (cont.):

(Guyton and Hall, 2001)

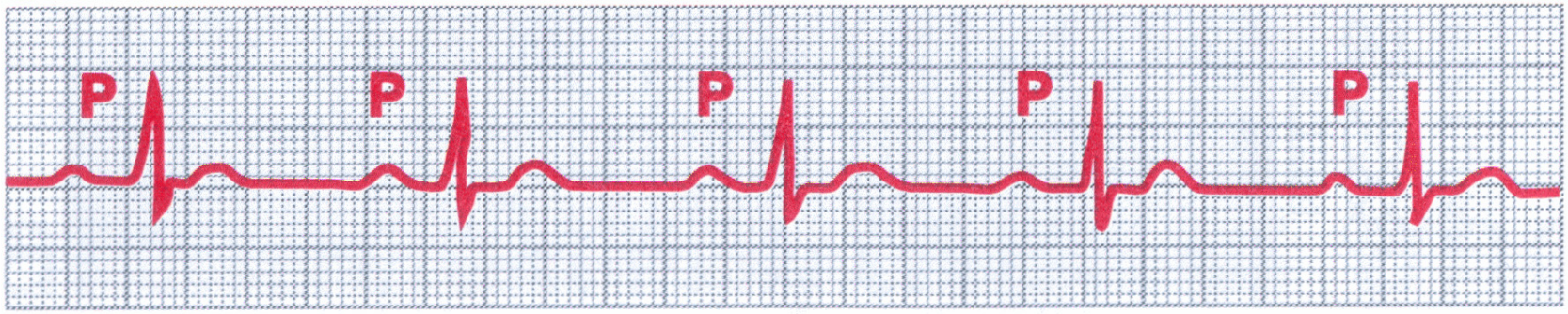


FIGURE 13–5

ECG Interpretation 101 (cont.):

(Guyton and Hall, 2001)

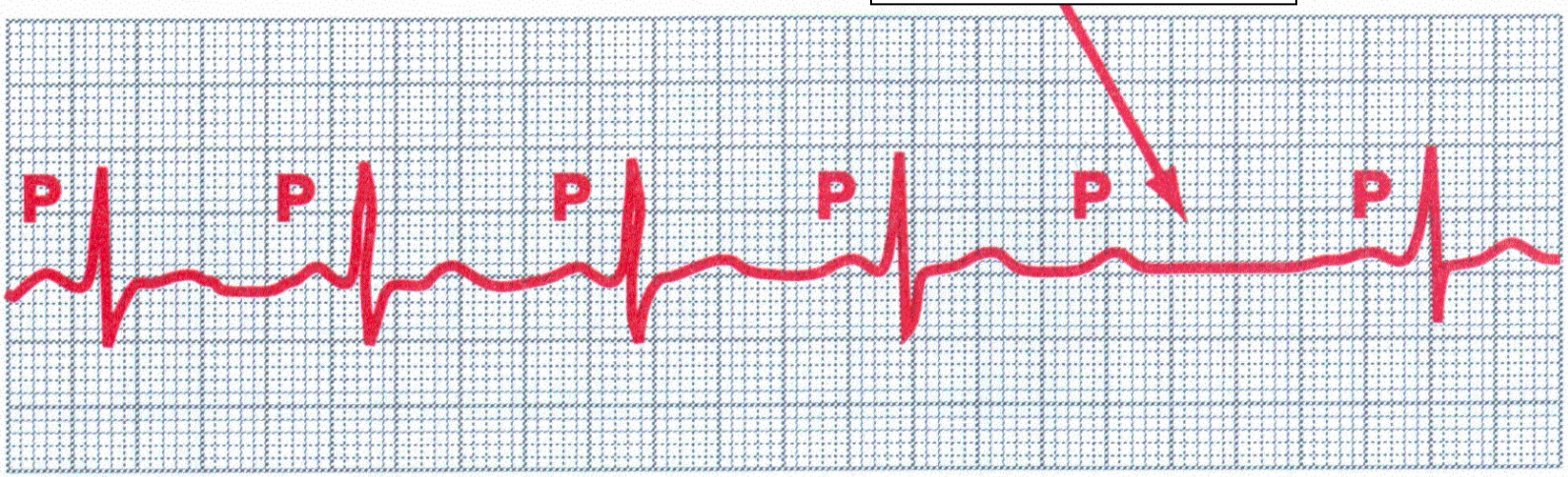


FIGURE 13–6

ECG Interpretation 101 (cont.):

(Guyton and Hall, 2001)

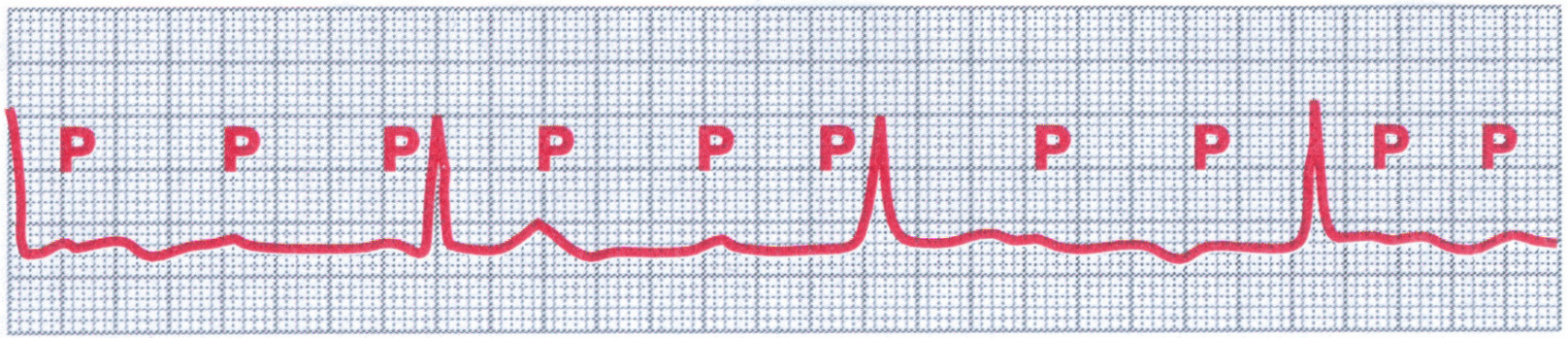


FIGURE 13–7

ECG Interpretation 101 (cont.):

(Guyton and Hall, 2001)

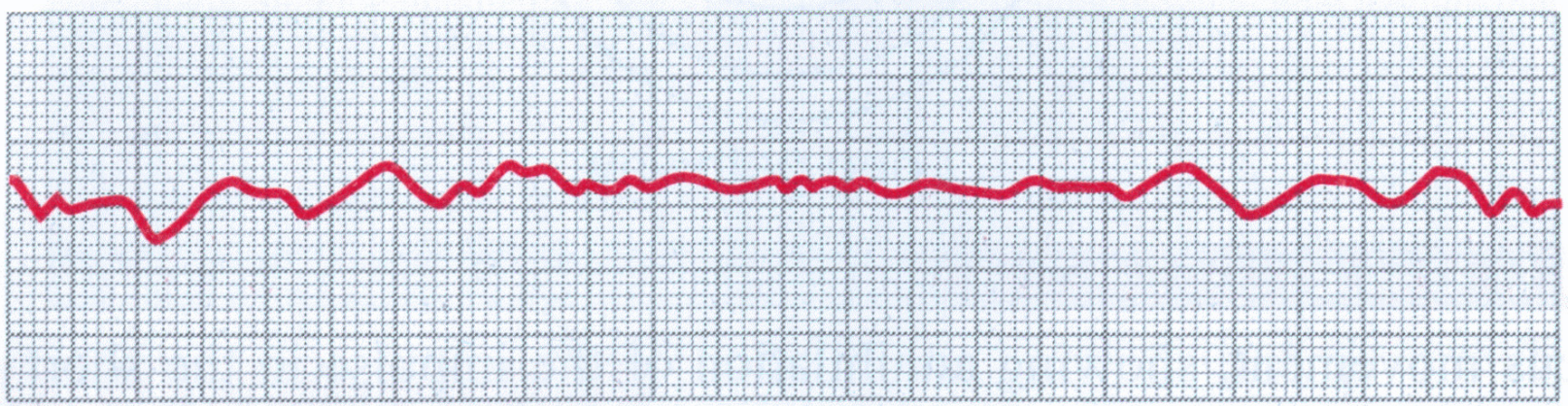


FIGURE 13–16

ECG Interpretation 101 (cont.):

(Guyton and Hall, 2001)

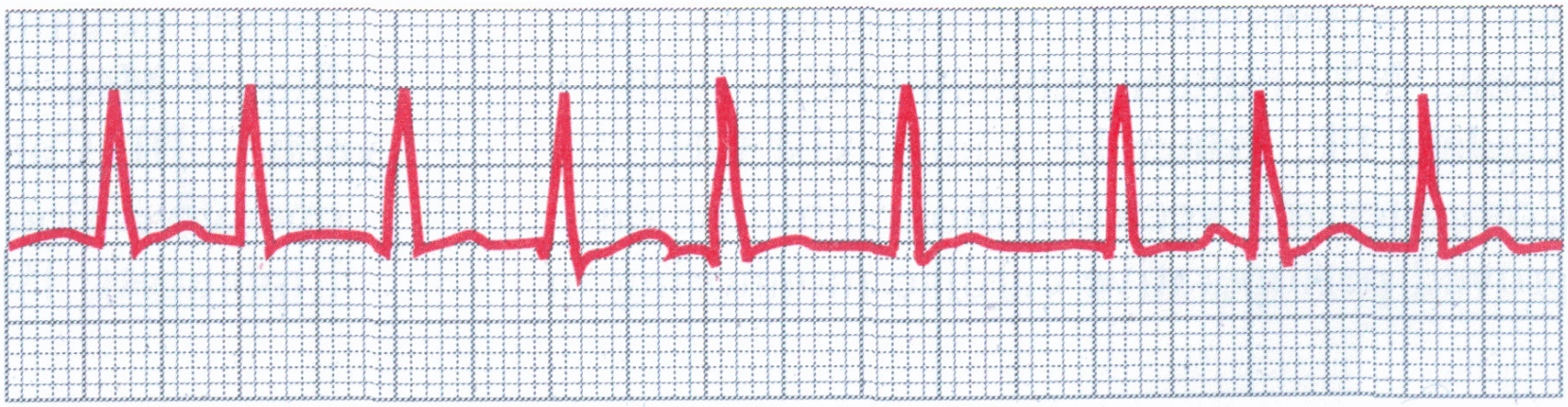


FIGURE 13–19

Pacemakers (cont.):

(Kaszala et al., 2008)

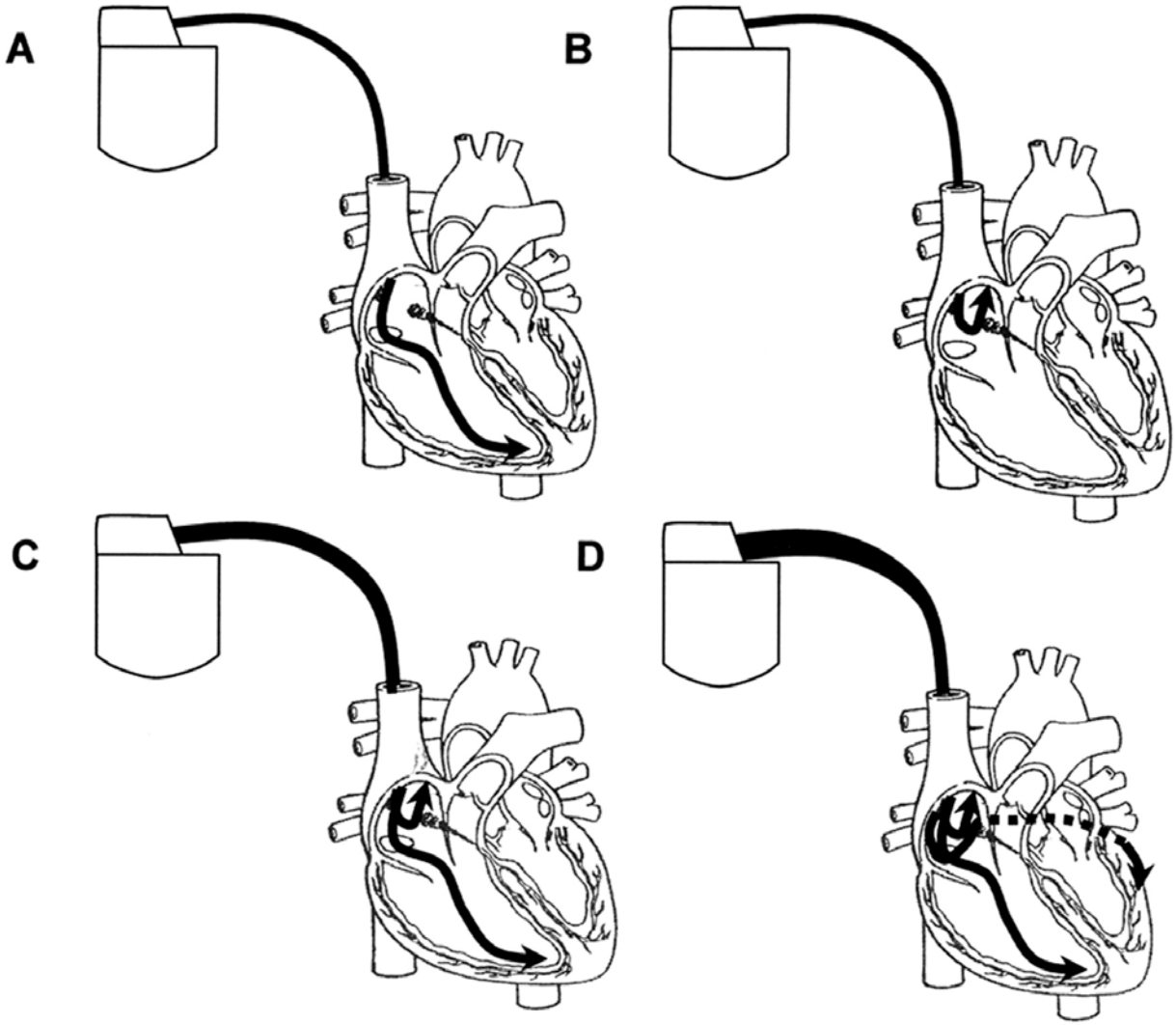


FIGURE 1. Schematic of commonly used pacemaker systems. A, Single-chamber ventricular pacemaker; B, Single-chamber atrial pacemaker; C, Dual-chamber pacemaker; D, Triple-chamber (biventricular) pacemaker.

Pacemakers (cont.):

The Revised NASPE/BPEG Generic Code for Antibradycardia Pacing

Position:	I	II	III	IV	V
Category:	**Chamber(s) Paced**	**Chamber(s) Sensed**	**Response to Sensing**	**Rate Modulation**	**Multisite Pacing**
	O = None	**O** = None	**O** = None	**O** = None	**O** = None
	A = Atrium	**A** = Atrium	**T** = Triggered	**R** = Rate modulation	**A** = Atrium
	V = Ventricle	**V** = Ventricle	**I** = Inhibited		**V** = Ventricle
	D = Dual (A + V)	**D** = Dual (A + V)	**D** = Dual (T + I)		**D** = Dual (A + V)
Manufacturers' designation only:	**S** = Single (A or V)	**S** = Single (A or V)			

(Bernstein et al., 2002)

Pacemakers (cont.):

(Bernstein et al., 2002)

Table II.
Examples of the Revised NASPE/BPEG Generic Code

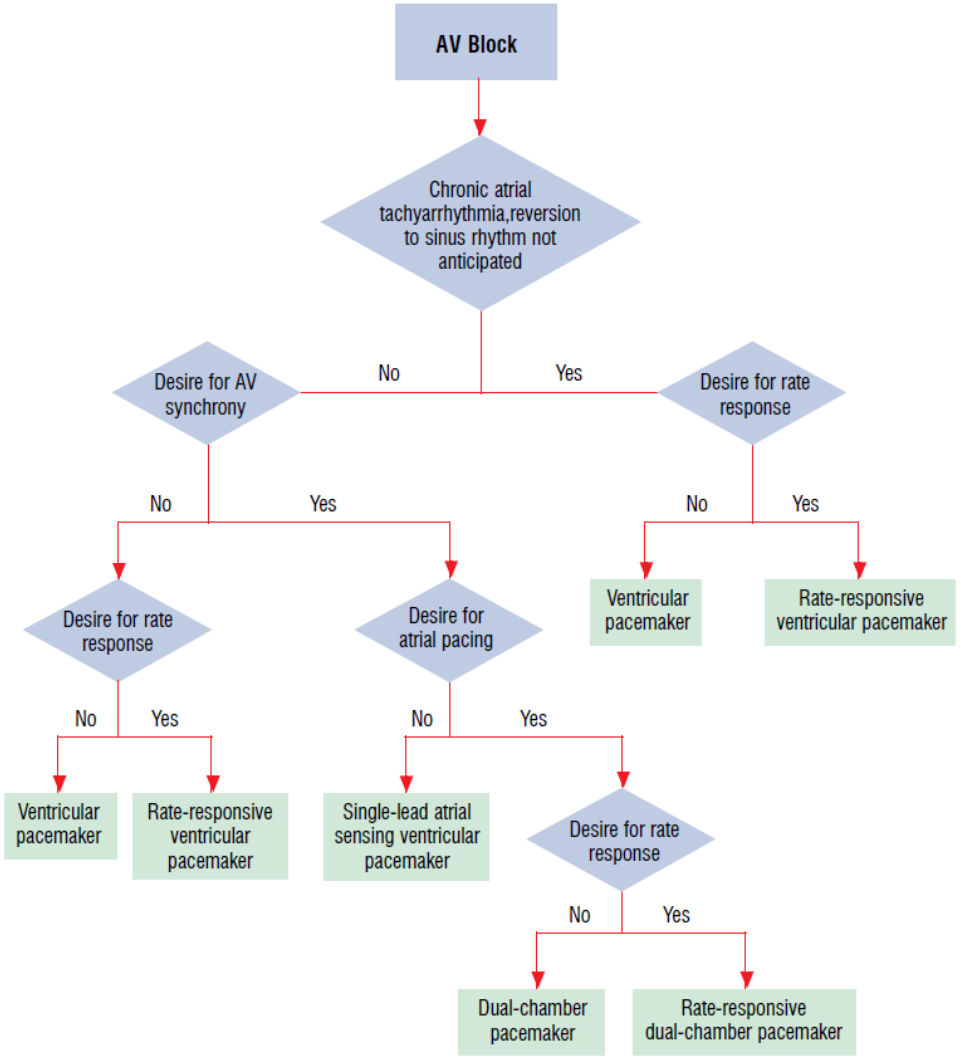
Code	Meaning
VOO, VOOO, or VOOOO	Asynchronous ventricular pacing; no sensing, rate modulation, or multisite pacing.
VVIRV	Ventricular inhibitory pacing with rate modulation and multisite ventricular pacing (i.e., biventricular pacing or more than one pacing site in one ventricle). This mode is often used in patients with heart failure, chronic atrial fibrillation, and intraventricular conduction delay.
AAI, AAIO, or AAIOO	Atrial pacing inhibited by sensed spontaneous atrial depolarizations; no rate modulation or multisite pacing.
AAT, AATO, or AATOO	Atrial pacing with atrial outputs elicited without delay on atrial sensing during the alert period outside the pulse generator's refractory period (used primarily as a diagnostic mode to determine exactly when atrial depolarizations are sensed); no rate modulation or multisite pacing.
AATOA	Atrial pacing with atrial outputs elicited without delay on atrial sensing during the alert period outside the pulse generator's refractory period, without rate modulation but with multisite atrial pacing (i.e., biatrial pacing, more than one pacing site in one atrium, or both features).
DDD, DDDO, or DDDOO	Dual chamber pacing (normally inhibited by atrial or ventricular sensing during the alert portion of the VA interval or by ventricular sensing during the alert portion of the AV interval, and with ventricular pacing triggered after a programmed PV interval by atrial sensing during the alert portion of the VA interval); no rate modulation or multisite pacing.
DDI, DDIO, or DDIOO	Dual chamber pacing without atrium synchronous ventricular pacing (atrial sensing merely cancels the pending atrial output without affecting escape timing); no rate modulation or multisite pacing.
DDDR or DDDRO	Dual chamber, adaptive-rate pacing; no multisite pacing.
DDDRA	Dual chamber, adaptive-rate pacing with multisite atrial pacing (i.e., biatrial pacing, more than one pacing site in one atrium, or both features). This mode was assessed in the multicenter DAPPAF study.[6]
DDDOV	Dual chamber pacing without rate modulation, but with multisite pacing (i.e., biventricular pacing, more than one pacing site in one ventricle, or both features).[7]
DDDRD	Dual chamber pacing with rate modulation and multisite pacing both in the atrium (i.e., biatrial pacing, pacing in more than one site in one atrium, or both features) and the ventricle (i.e., biventricular pacing, pacing in more than one site in one ventricle, or both features).

Pacemakers (cont.):

(ACC/AHA Guidelines, Epstein et al., *Circulation* 2008)

Figure 1. Selection of Pacemaker Systems for Patients With Atrioventricular Block

Decisions are illustrated by diamonds. Green shaded boxes indicate type of pacemaker.



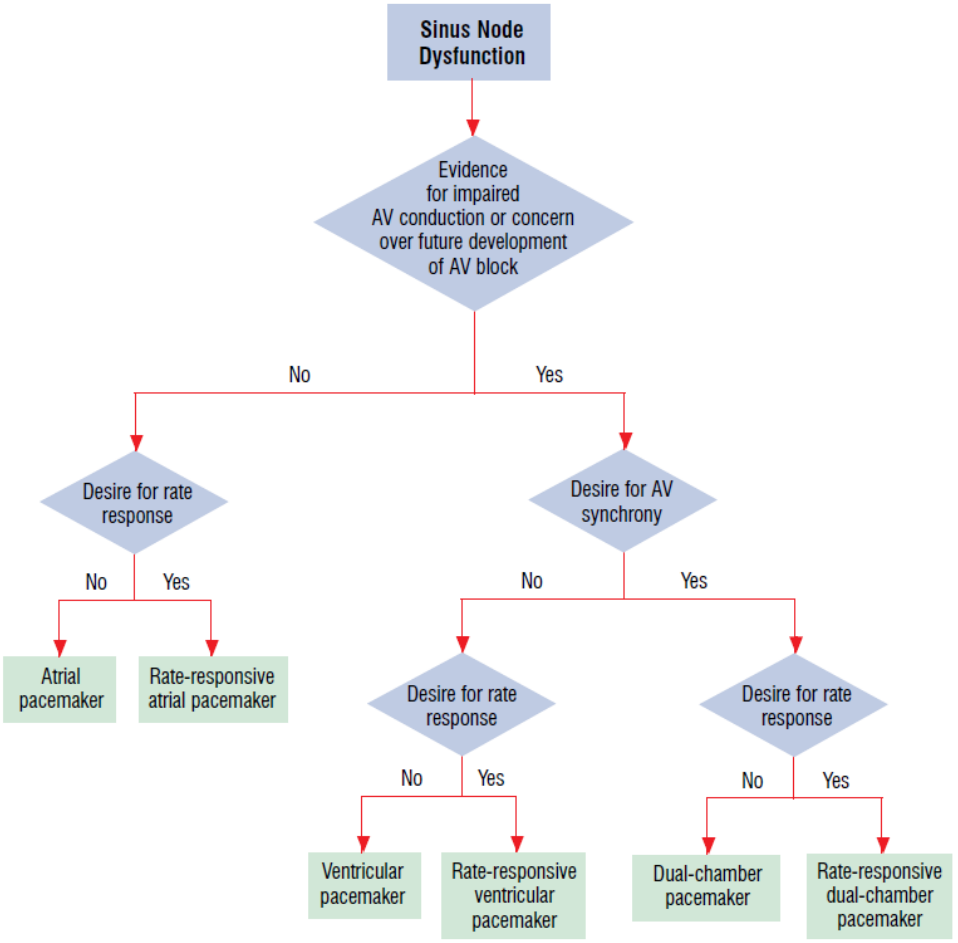
AV indicates atrioventricular.

Pacemakers (cont.):

(ACC/AHA Guidelines, Epstein et al., *Circulation* 2008)

Figure 2. Selection of Pacemaker Systems for Patients With Sinus Node Dysfunction

Decisions are illustrated by diamonds. Green shaded boxes indicate type of pacemaker.



AV indicates atrioventricular.

Pacemakers (cont.):

(ACC/AHA Guidelines, Epstein et al., *Circulation* 2008)

Table 2. Choice of Pacemaker Generator in Selected Indications for Pacing

Pacemaker Generator	Sinus Node Dysfunction	Atrioventricular Block	Neurally Mediated Syncope or Carotid Sinus Hypersensitivity
Single-chamber atrial pacemaker	No suspected abnormality of atrioventricular conduction and not at increased risk for future atrioventricular block Maintenance of atrioventricular synchrony during pacing desired	Not appropriate	Not appropriate
Single-chamber ventricular pacemaker	Maintenance of atrioventricular synchrony during pacing not necessary Rate response available if desired	Chronic atrial fibrillation or other atrial tachyarrhythmia or maintenance of atrioventricular synchrony during pacing not necessary Rate response available if desired	Chronic atrial fibrillation or other atrial tachyarrhythmia Rate response available if desired
Dual-chamber pacemaker	Atrioventricular synchrony during pacing desired Suspected abnormality of atrioventricular conduction or increased risk for future atrioventricular block Rate response available if desired	Rate response available if desired Atrioventricular synchrony during pacing desired Atrial pacing desired Rate response available if desired	Sinus mechanism present Rate response available if desired
Single-lead, atrial-sensing ventricular pacemaker	Not appropriate	Desire to limit the number of pacemaker leads	Not appropriate

Implantable cardioverter-defibrillators:

Similar to cardiac pacemakers, but with:

- ability to deliver larger defibrillating shocks,
- larger shock coil electrodes, and
- more sophisticated microprocessor.

Table I.

The NASPE/BPEG Defibrillator (NBD) Code

I **Shock Chamber**	II **Antitachycardia Pacing Chamber**	III **Tachycardia Detection**	IV **Antibradycardia Pacing Chamber**
O = None **A** = Atrium **V** = Ventricle **D** = Dual (A + V)	**O** = None **A** = Atrium **V** = Ventricle **D** = Dual (A + V)	**E** = Electrogram **H** = Hemodynamic	**O** = None **A** = Atrium **V** = Ventricle **D** = Dual (A + V)

(Bernstein et al., *PACE* 1993)

ICDs (cont.):

(Bernstein et al., *PACE* 1993)

Table III.

Examples of the Use of the NASPE/BPEG Defibrillator (NBD) Code*

Device	Short Form	Long Form	Label
Ventricle-only ICD without pacing	ICD-S	VO VOE VOEO	VOE-OOOO
Ventricle-only ICD with VVIR antibradycardia pacing	ICD-B	VO VOE VOEV	VOE-VVIR
Ventricle-only ICD with atrial antitachycardia pacing and DDDC antibradycardia pacing	ICD-T	VA VAE VAED	VAE-DDDC
ICD with ventricular cardioversion/defibrillation, dual chamber antitachycardia pacing, and DDDR antibradycardia pacing	ICD-T	VD VDE VDED	VDE-DDDR
Atrium-only ICD with cardioversion, antitachycardia pacing, and AAIC antibradycardia pacing	ICD-T	AA AAE AAEA	AAE-AAIC
ICD with ventricular cardioversion/defibrillation, AF conversion, hemodynamic sensing, and VVIR antibradycardia pacing	ICD-S	DOH DOHV	DOH-VVIR
ICD with ventricular cardioversion/defibrillation, AF conversion, dual chamber antitachycardia pacing, and DDD antibradycardia pacing with telemetry	ICD-T	DD DDE DDED	DDE-DDDC
ICD with ventricular cardioversion/defibrillation, AF conversion, hemodynamic sensing, dual chamber antitachycardia pacing, and DDDR antibradycardia pacing	ICD-T	DDH DDHD	DDH-DDDR

AF = atrial fibrillation or atrial flutter; ICD = implanted cardioverter defibrillator.
* In each instance, the Code refers to the maximal capabilities of the device.