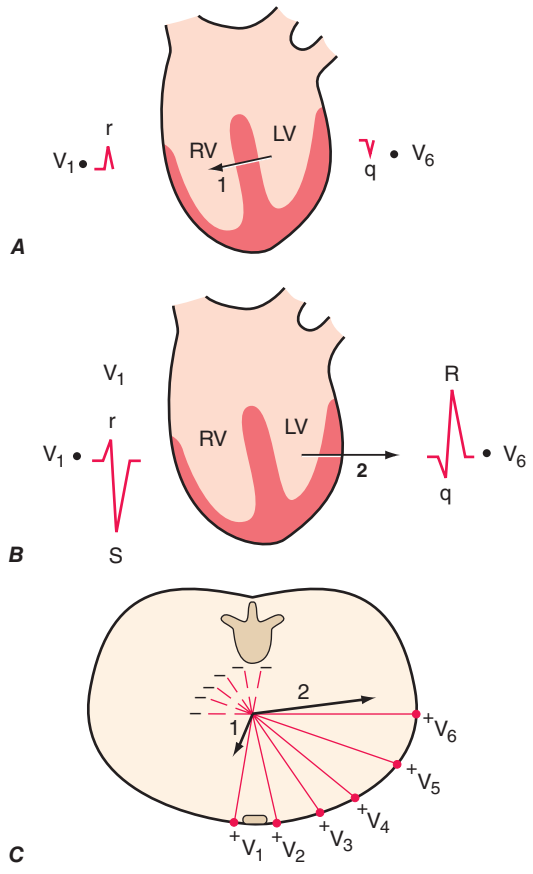

FIGURE 268-6 Ventricular depolarization can be divided into two major phases, each represented by a vector. *A.* The first phase (*arrow 1*) denotes depolarization of the ventricular septum, beginning on the left side and spreading to the right. This process is represented by a small "septal" r wave in lead V_1 and a small septal q wave in lead V_6. ***B.*** Simultaneous depolarization of the left and right ventricles (LV and RV) constitutes the second phase. Vector 2 is oriented to the left and posteriorly, reflecting the electrical predominance of the LV. ***C.*** Vectors (*arrows*) representing these two phases are shown in reference to the horizontal plane leads. *(After AL Goldberger et al: Goldberger's Clinical Electrocardiography: A Simplified Approach, 8th ed. Philadelphia, Elsevier/Saunders, 2013.)*

the R and S waves are of approximately equal amplitude is referred to as the *transition zone* (usually V_3 or V_4) (Fig. 268-7).

The QRS pattern in the extremity leads may vary considerably from one normal subject to another depending on the *electrical axis* of the QRS, which describes the mean orientation of the QRS vector with reference to the six frontal plane leads. Normally, the QRS axis ranges from −30° to +100° (Fig. 268-4). An axis more negative than −30° is referred to as *left axis deviation*, and an axis more positive than +100° is referred to as *right axis deviation*. Left axis deviation may occur as a normal variant but is more commonly associated with left ventricular hypertrophy, a block in the anterior fascicle of the left bundle system (left anterior fascicular block or hemiblock), or inferior myocardial infarction. Right axis deviation also may occur as a normal variant (particularly in children and young adults), as a spurious finding due to reversal of the left and right arm electrodes, or in conditions such as right ventricular overload (acute or chronic), infarction of the lateral wall of the left ventricle, dextrocardia, left pneumothorax, and left posterior fascicular block.

T WAVE AND U WAVE

Normally, the mean T-wave vector is oriented roughly concordant with the mean QRS vector (within about 45° in the frontal plane). Since depolarization and repolarization are electrically opposite processes, this normal QRS–T-wave vector concordance indicates that repolarization normally must proceed in the reverse direction from depolarization (i.e., from ventricular epicardium to endocardium). The normal U wave is a small, rounded deflection (≤1 mm) that follows the T wave and usually has the same polarity as the T wave. An abnormal increase in U-wave amplitude is most commonly due to drugs (e.g., dofetilide, amiodarone, sotalol, quinidine) or to hypokalemia. Very prominent U waves are a marker of increased susceptibility to the *torsades de pointes* type of ventricular tachycardia (Chap. 276). Inversion of the U wave in the precordial leads is abnormal and may be a subtle sign of ischemia.

MAJOR ECG ABNORMALITIES

CARDIAC ENLARGEMENT AND HYPERTROPHY

Right atrial overload (acute or chronic) may lead to an increase in P-wave amplitude (≥2.5 mm) (Fig. 268-8), sometimes referred to as "P-pulmonale." Left atrial overload typically produces a biphasic P wave in V_1 with a broad negative component or a broad (≥120 ms), often notched P wave in one or more limb leads (Fig. 268-8). This pattern, previously referred to as "P-mitrale," may also occur with left atrial conduction delays in the absence of actual atrial enlargement, leading to the more general designation of *left atrial abnormality*.

Right ventricular hypertrophy due to a sustained, severe pressure load (e.g., due to tight pulmonic valve stenosis or certain pulmonary artery hypertension syndromes) is characterized by a relatively tall R wave in lead V_1 (R ≥ S wave), usually with right axis deviation (Fig. 268-9); alternatively, there may be a qR pattern in V_1 or V_3R. ST depression and T-wave inversion in the right-to-midprecordial leads are also often present. This pattern, formerly called right ventricular "strain," is attributed to repolarization abnormalities in acutely or chronically overloaded muscle. Prominent S waves may occur in the left lateral precordial leads. Right ventricular hypertrophy due to ostium secundum–type atrial septal defects, with the accompanying

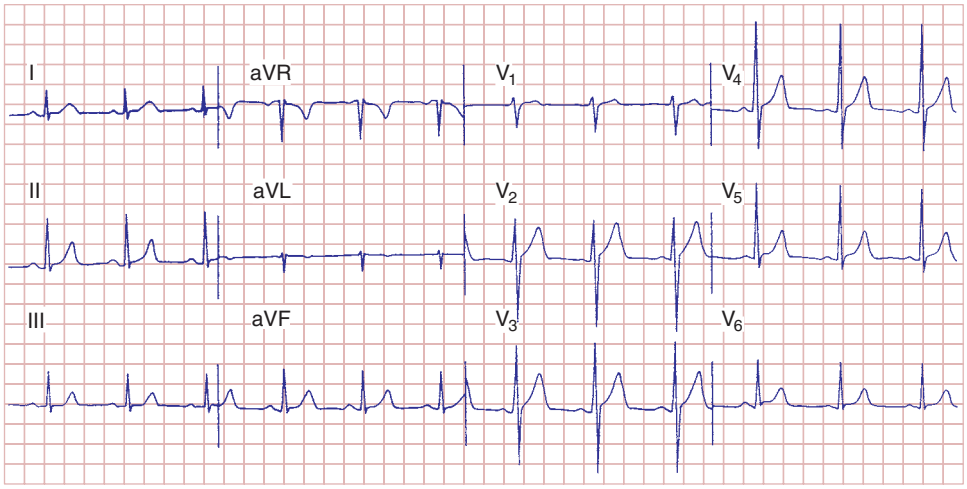

FIGURE 268-7 Normal electrocardiogram from a healthy subject. Sinus rhythm is present with a heart rate of 75 beats per minute. PR interval is 0.16 s; QRS interval (duration) is 0.08 s; QT interval is 0.36 s; QT_c is 0.40 s; the mean QRS axis is about +70°. The precordial leads show normal R-wave progression with the transition zone (R wave = S wave) in lead V_3.