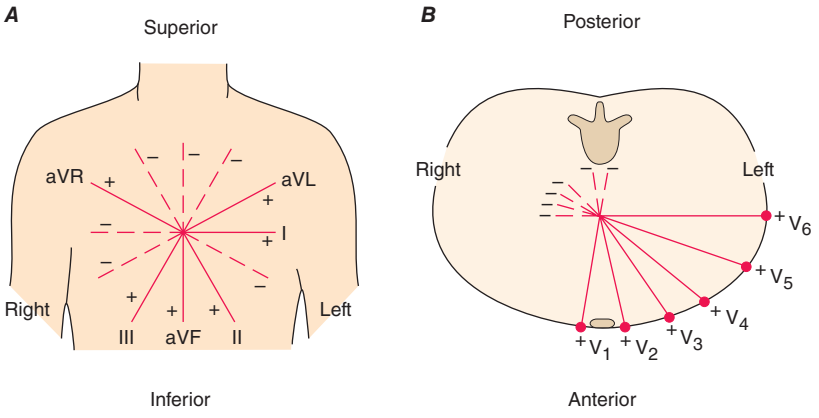

FIGURE 268-3 The six frontal plane (***A***) and six horizontal plane (***B***) leads provide a three-dimensional representation of cardiac electrical activity.

The spatial orientation and polarity of the six frontal plane leads is represented on the hexaxial diagram (Fig. 268-4). The six chest leads (Fig. 268-5) are unipolar recordings obtained by electrodes in the following positions: lead V_1, fourth intercostal space, just to the right of the sternum; lead V_2, fourth intercostal space, just to the left of the sternum; lead V_3, midway between V_2 and V_4; lead V_4, midclavicular line, fifth intercostal space; lead V_5, anterior axillary line, same level as V_4; and lead V_6, midaxillary line, same level as V_4 and V_5. Additional posterior leads are sometimes placed on the same horizontal plane as V_4 to facilitate detection of acute posterolateral infarction (V_7, midaxillary line; V_8 posterior axillary line; and V_9, posterior scapular line).

Together, the frontal and horizontal plane electrodes provide a three-dimensional representation of cardiac electrical activity. Each lead can be likened to a different video camera angle "looking" at the same events—atrial and ventricular depolarization and repolarization—from different spatial orientations. The conventional 12-lead ECG can be supplemented with additional leads in special circumstances. For example, right precordial leads V_3R, V_4R, etc., are useful in detecting evidence of acute right ventricular ischemia. Bedside monitors and ambulatory ECG (Holter) recordings usually employ only one or two modified leads. Intracardiac electrocardiography and electrophysiologic testing are discussed in Chaps. 274 and 276.

The ECG leads are configured so that a positive (upright) deflection is recorded in a lead if a wave of depolarization spreads toward the positive pole of that lead, and a negative deflection is recorded if the wave spreads toward the negative pole. If the *mean* orientation of the depolarization vector is at right angles to a particular lead axis, a biphasic (equally positive and negative) deflection will be recorded.

GENESIS OF THE NORMAL ECG

P WAVE

The normal atrial depolarization vector is oriented downward and toward the subject's left, reflecting the spread of depolarization from the sinus node to the right and then the left atrial myocardium. Since this vector points toward the positive pole of lead II and toward the negative pole of lead aVR, the normal P wave will be positive in lead II and negative in lead aVR. By contrast, activation of the atria from an ectopic pacemaker in the lower part of either atrium or in the AV junction region may produce retrograde P waves (negative in lead II, positive in lead aVR). The normal P wave in lead V_1 may be biphasic with a positive component reflecting right atrial depolarization, followed by a small (<1 mm²) negative component reflecting left atrial depolarization.

QRS COMPLEX

Normal ventricular depolarization proceeds as a rapid, continuous spread of activation wave fronts. This complex process can be divided into two major sequential phases, and each phase can be represented by a mean vector (Fig. 268-6). The first phase is depolarization of the interventricular septum from the left to the right and anteriorly (vector 1). The second results from the simultaneous depolarization of the right and left ventricles; it normally is dominated by the more massive left ventricle, so that vector 2 points leftward and posteriorly. Therefore, a right precordial lead (V_1) will record this biphasic depolarization process with a small positive deflection (septal r wave) followed by a larger negative deflection (S wave). A left precordial lead, e.g., V_6, will record the same sequence with a small negative deflection (septal q wave) followed by a relatively tall positive deflection (R wave). Intermediate leads show a relative increase in R-wave amplitude (normal R-wave progression) and a decrease in S-wave amplitude progressing across the chest from right to left. The precordial lead where

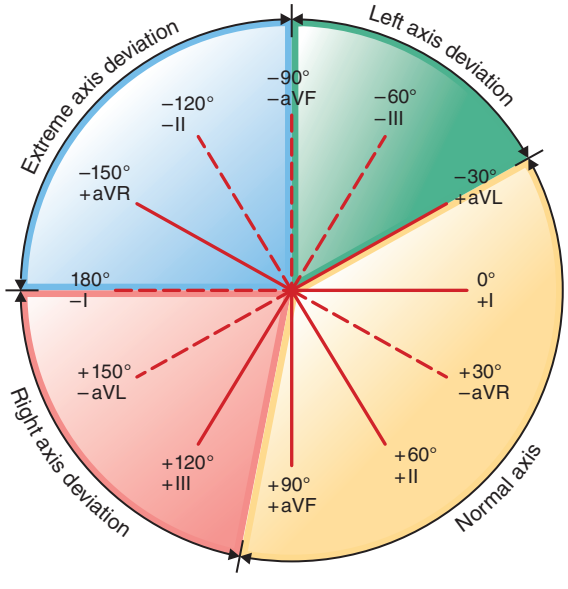

FIGURE 268-4 **The frontal plane (limb or extremity) leads** are represented on a hexaxial diagram. Each ECG lead has a specific spatial orientation and polarity. The positive pole of each lead axis (*solid line*) and the negative pole (*hatched line*) are designated by their angular position relative to the positive pole of lead I (0°). The mean electrical axis of the QRS complex is measured with respect to this display.

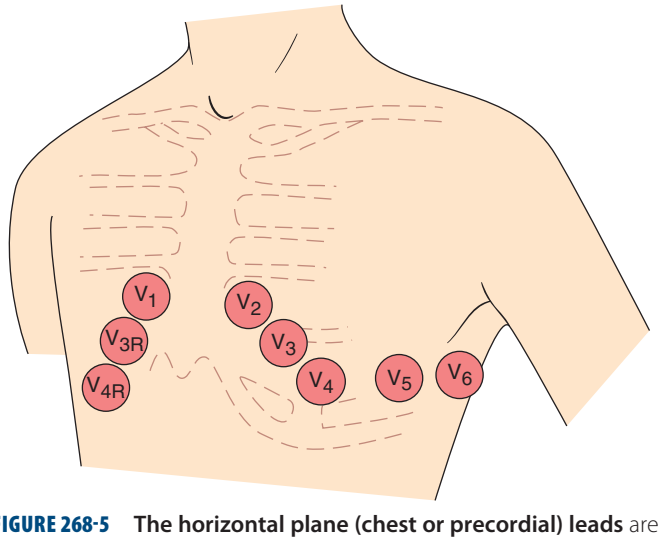

FIGURE 268-5 **The horizontal plane (chest or precordial) leads** are obtained with electrodes in the locations shown.