PART III: NORMAL AND ABNORMAL AUTOMATICITY

6. PHYSIOLOGICAL BASIS OF NORMAL AND ABNORMAL AUTOMATICITY

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I. INTRODUCTION

The general plan of this chapter is first to define normal and abnormal automaticity and then to discuss the physiological basis of these two forms of spontaneous discharge. The physiological basis should in turn permit to identify some of the characteristics of normal and abnormal automaticity which may be useful also from a clinical point of view. There have been several developments in this field recently and several reviews are available which cover different aspects of this field (Cranefield 1975, 1979; Vassalle 1977a, 1979; Irisawa 1978; Sperelakis and Vogel 1981). One particular development is mentioned in this introduction, namely the interpretation of the pacemaker current as an increasing inward current (rather than a decaying outward current) in both the sinus node and in Purkinje fibers. In the presentation to follow the concept of a decaying outward current is retained and the newer findings are then illustrated and discussed. This not only will facilitate the understanding of available literature but also will permit a comparison of different findings on which the reader can base conclusions.

II. AUTOMATICITY

During a normal cardiac cycle, all cardiac cells are activated through a depolarization of the membrane potential to the threshold potential. This is accomplished in two ways: through diastolic depolarization in the dominant pacemaker cells in the sinus node and through the electrotonic interactions characteristic of the conduction process in the rest of the cardiac cells. Automaticity is the ability to initiate excitation in the absence of external stimuli and, therefore, is present only when excitation is due to the attainment of threshold by diastolic depolarization. The decline in membrane potential to the threshold depends on local changes in membrane conductances and it is not determined (although it can be modified) by interactions with other cells. By definition both normal and abnormal automaticity must
share the common characteristics of attaining the threshold through a depolarizing process in diastole. The difference resides in the nature or the magnitude of such depolarizing process under different conditions.

III. NORMAL VS. ABNORMAL AUTOMATICITY

A. Anatomical considerations

Strictly speaking, normal automaticity should reside only in the sinus node and nowhere else in the heart. However, this relatively simple statement meets with difficulties in several respects. First of all, even in the sinus node some cells are excited through the process of conduction. In addition, the initiation of the heart beat could be originating in the sinus node and still be abnormal (for example, local reentry or extrasystoles). And an impulse originating outside the sinus node is not ipso facto abnormal. This is so because under certain circumstances (e.g. complete atrio-ventricular block), a slow idioventricular rhythm is indeed a normal event and its absence would be highly abnormal. From this point of view, normal automaticity is not an exclusive prerogative of a single heart tissue and automaticity is not necessarily normal just because it originates in the sinus node. Normal automaticity must be then defined in some way other than the tissue from which it originates.

B. Physiological considerations

From a functional point of view normal automaticity can be identified with a process which requires diastolic depolarization, namely a slow decline of membrane potential during diastole. Identifying diastolic depolarization as the basis for normal automaticity has the advantage that it excludes arrhythmias which depend on conduction such as reentry. The definition also includes (as it should) all the specialized cardiac tissues, for these tissues can become active pacemakers. However, the need remains to differentiate normal diastolic depolarization from the events leading to abnormal automaticity. In addition, we are still left with the problem of the quantitative aspects of normal automaticity. The boundary of normality can be defined on a statistical basis and automaticity can be considered normal when it is caused by a diastolic depolarization which results in a rate comprised between two sets of values. For example, 60-100 beats/min for the sinus rhythm of a normal human subject at rest or 20-40 beats/min for the idioventricular rhythm of a patient with complete atrioventricular block. If normal automaticity then can be defined as caused by a diastolic depolarization