

THE CARDIAC RHYTHMS

A Systematic Approach to Interpretation

SECOND EDITION

RAYMOND E. PHILLIPS, M.D., F.A.C.P.

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PREFACE

to the Second Edition

In the decade since we started the first edition of *The Cardiac Rhythms*, there have been tremendous advances in the understanding of cardiac arrhythmias. These developments have altered both the conceptual basis of the subject and its practical application.

Much of this progress in interpreting arrhythmias is due to information derived from correlating clinical electrocardiography with intracardiac recordings of impulse formation-impulse conduction systems. These correlates have formed the basis for a better understanding of the mechanisms responsible for disorders of the heartbeat. Indeed, these principles of electrophysiology—presented first at a simplified level and thereafter developed sequentially as they pertain to the various classes of rhythms—constitute a major area of revision of this book.

Several clinical topics, such as sinus node dysfunction, re-entrant mechanisms of ectopic beats, and intraventricular conduction defects, have been considerably expanded and updated as a result of recent research. An additional subject of particular importance in the interpretation of cardiac rhythms is the differentiation between ventricular rhythms and supraventricular rhythms with aberrant ventricular conduction. A detailed series of guidelines for this differentiation is now provided. The terminology pertaining to electronic pacemaker therapy has also been revised, in keeping with current usage. In addition, the chapter on drugs has been updated and expanded to include some of the more important, or promising, newer agents.

Another new feature in this edition is the introduction of electrocardiographic criteria for several major clinical entities not directly involving rhythm disturbances. Examples include the exercise stress test, myocardial infarction and ischemia, electrical axis deviation, and chamber enlargement. The descriptions of these entities are briefly stated and illustrated, and are intended to increase the reader's awareness of the scope of general electrocardiography. The focus of this text, however, remains on disorders of rhythms.

To the principal editor, Katherine Pitcoff, Nursing Editor at W. B. Saunders, we express our deepest appreciation, for her guidance, encouragement, and attention to the endless details of manuscript and proof preparations. A difficult task as

copy editor has been fulfilled with exceptional competence by Susan Thomas. We would also like to take this opportunity to thank the original editors of *The Cardiac Rhythms*, Helen Dietz and Robert Wright, formerly of W. B. Saunders, who were so instrumental in steering us toward the final text and who in so many ways contributed to the design and style of the book.

Raymond E. Phillips

Mary K. Feeney

In the decade since we started the first edition of *The Cardiac Rhythms*, there have been tremendous advances in the understanding of cardiac arrhythmias. These developments have altered both the conceptual basis of the subject and its practical application. Much of this progress in interpreting arrhythmias is due to information derived from noninvasive clinical electrocardiography with intracardiac recordings of impulse formation-ventricular conduction systems. These correlates have formed the basis for a better understanding of the mechanisms responsible for disorders of the heart. Indeed, these principles of electrophysiology—presented first at a simplified level and thereafter developed sequentially as they pertain to the various classes of rhythms—constitute a major area of revision of this book. Several clinical topics such as sinus node dysfunction, re-entrant mechanisms of ectopic beats, and myocardial conduction defects, have been considerably expanded and updated as a result of recent research. An additional subject of particular importance in the interpretation of cardiac rhythms is the differentiation between ventricular rhythms and supraventricular rhythms with aberrant ventricular conduction. A detailed series of guidelines for this differentiation is now provided. The terminology pertaining to electrical pacemaker therapy has also been revised to keep pace with current usage. In addition, the chapter on drugs has been updated and expanded to incorporate of the more important or promising newer agents. Another new feature in this edition is the introduction of electrocardiographic criteria for several major clinical entities not fully involving rhythm disorders. Examples include the exercise stress test, myocardial infarction and ischemia, electrical axis deviation, and chamber enlargement. The descriptions of these entities are briefly stated and illustrated, and are intended to increase the reader's awareness of the scope of general electrocardiography. The focus of this text, however, remains on disorders of rhythm. In the principal editor, Katherine Lippell, former Editor at W. B. Saunders, we express our deepest appreciation for her guidance, encouragement, and stimulation to the authors during the many years of preparation. A difficult task

PREFACE

to the First Edition

The Cardiac Rhythms presents a plan for acquiring skill in the electrocardiographic interpretation of the heartbeat. The subject is introduced on an elementary level and developed to an intermediate degree of complexity. The orientation is directed in particular to preparing the reader for the Cardiac Care Unit experience.

The book has been designed as a primer for self-study and is intended to help the student recognize and describe the common disorders of the cardiac rhythm. The reader who is already familiar with the fundamentals of the subject can gain further proficiency in analysis through the numerous examples of arrhythmias and clinical rhythm sequences. The book is also useful as an illustrative outline and exercise supplement for a formal course or for group instruction. For the cardiac care team, the system of presentation may serve as a guide for standardizing clinical description and for organizing a unit logbook of arrhythmias.

The text has been integrated into a stylized pictorial frame of reference with a step-by-step exposition of the basic determinants of heart rate and rhythm. The dynamics of the normal heartbeat are given considerable attention to establish a sound working knowledge of physiological principles before proceeding to the more difficult abnormal rhythms. Pertinent effects of the autonomic nervous system and the cardiac drugs are introduced early in the text and are expanded within the schematic framework. Anatomical and electrophysiological details are included only to that depth which is essential for the interpretation of the cardiac rhythms.

While all disturbances of the heartbeat fall within a relatively few basic types, they appear in endless variations of a given pattern and in combinations of patterns. Because of this, multiple examples of each class are provided. A workbook format has been followed so that the reader may actively participate in problem solving while developing the practice of careful search and accurate diagnosis. Emphasis is placed on the use of descriptive terminology and comprehensive interpretation. At various stages in the book, test electrocardiograms are presented to give the reader an opportunity to evaluate his progress.

We wish to thank the staff of the Coronary Care Unit at Phelps Memorial Hospital, North Tarrytown, New York, where many ideas for this presentation were formulated.

R.P.

M.K.F.

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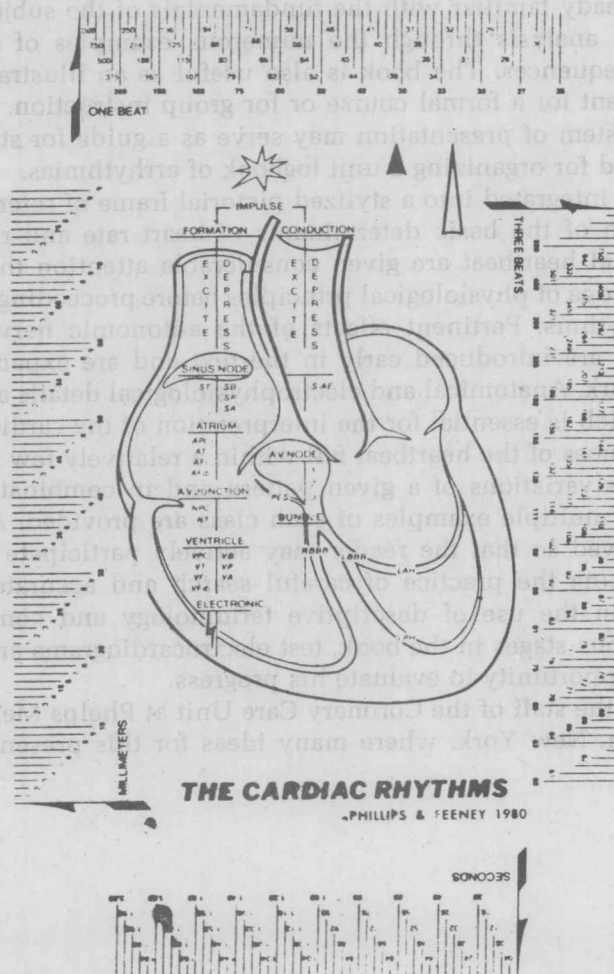
CARDIAC SYMBOL SHEET

Sheets containing more than 800 of the symbols shown here are available for five dollars a sheet. These dry, press-on transfer figures are useful for annotating electrocardiographic records.



CARDIAC RHYTHM RULER

A plastic, color-coded version of this pocket-sized ruler is available for one dollar. The ruler contains a One-beat and a Three-beat rate scale, a scale for determining intervals in seconds, and a millimeter measure. A cardboard version is included for your convenience.



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Chapter 1

THE HEARTBEAT

The heart is a hollow, compact muscular organ that functions in one way only — as a pump. Yet the work of this pump must be sensitively responsive to the peripheral circulation and its ever changing demands, created by exercise, position, temperature, digestion, and emotional excitement. Although the basic function of the heart is simple in principle, the adaptive variations in cardiac output from moment to moment are smoothly integrated by mechanisms that are extremely complex.

Normally, the mechanisms governing the heartbeat produce a well-defined pattern that determines how fast the heart beats and the sequence in which various portions of it are activated. The recognition of the disturbances of cardiac rate and sequential order of activation, as displayed on the electrocardiogram, is the subject of this book.

A DEVELOPMENTAL ANATOMY

The heart can be visualized as a rather simple structure of four chambers, two on top (the atria) and two on the bottom (the ventricles): From a functional viewpoint, the simple model is useful: the right-sided chambers receive vessels from the body in general (the systemic venous system) and lead to the lungs; the left-sided chambers receive vessels from the lungs and lead to the rest of the body (the systemic arterial system). Anatomically, however, the heart is quite complicated and the spatial relationships between its components somewhat difficult to envision.

Basically, the heart can be thought of as a loop in a tubular structure. Since the chambers are divided in the middle, the tube has the form of a double-barreled shotgun. Each barrel possesses two valves that limit the flow of blood to one direction only. Seemingly far-fetched, this analogy can be appreciated with a simplified explanation of the development of the heart in the embryo. This vantage point may serve to develop a practical image of the heart and the relationships between its structure and function.

In the human embryo, the future heart can be identified by the end of the second week of life as a bulbous muscular enlargement of the primary cardiac tube, a ventral midline channel that forms the primitive circulatory system (Fig. 1-1). Sometime during the fourth week of life, peristaltic waves appear in the bulb, each beginning at the hind end and proceeding to the fore end. By this mechanism, blood is

propelled forward within the tube much as food residues are moved along by peristalsis in the intestine. This peristaltic activity constitutes the rudimentary heartbeat, at first infrequent and irregular but gradually increasing in rate and rhythmicity.

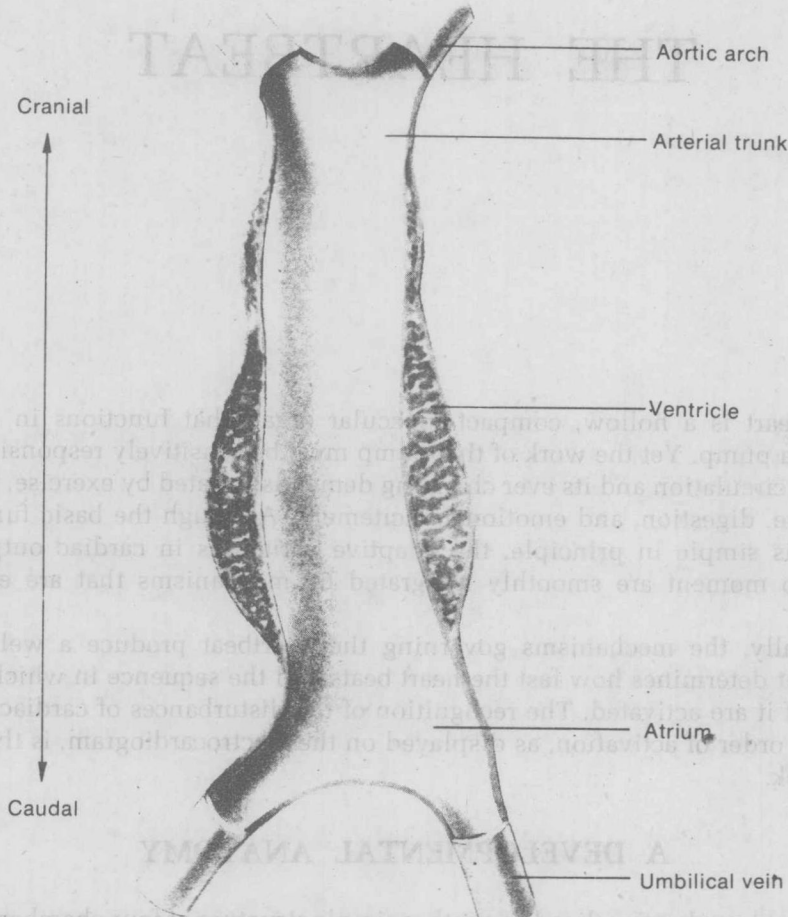


Figure 1-1. Cutaway view of the primitive cardiac tube.

Even the earliest heartbeats have three fundamental properties. Despite the increasing complexity of these functional components, they nevertheless are preserved in the fully developed heart. They are:

1. *Impulse formation*: the origin of an electrical disturbance (or current) in a cardiac cell that is capable of stimulating adjacent cardiac cells. This property is referred to as **automaticity** (or self-excitation).

2. *Impulse conduction*: the propagation of the electrical disturbance from one cardiac cell to another. Cells that are responsive to a stimulus from another cell exhibit the property of **excitability**; the capability of passing on the stimulus to other cells is termed **conductivity**.

3. *Contraction*: the shortening of cardiac cells in response to a stimulus. The pumping action of the heart is produced by the harmonious contraction of all the muscle cells of the heart.

Later in the individual's development, these three functional components of the heartbeat will be taken over by specialized cardiac cells. Some become responsible for impulse formation, initiating each heart beat. Other cells form the conduction pathways that carry the pacemaker impulse throughout the heart. By far the largest portion of cells remain as the basic units of contraction, the myofibrils.

The primary cardiac bulb undergoes rapid growth and differential development. As it grows longer, it twists upon itself and assumes an abrupt S-shaped contour (Fig. 1-2). As a result, the hind (or venous) end is brought further headward than the original forward (or arterial) end of the tube. The enlargement at the venous end is destined to become the atrial chambers and to receive blood from the periphery. The enlargement at the arterial end will become the ventricles and will expel blood to the peripheral organs.

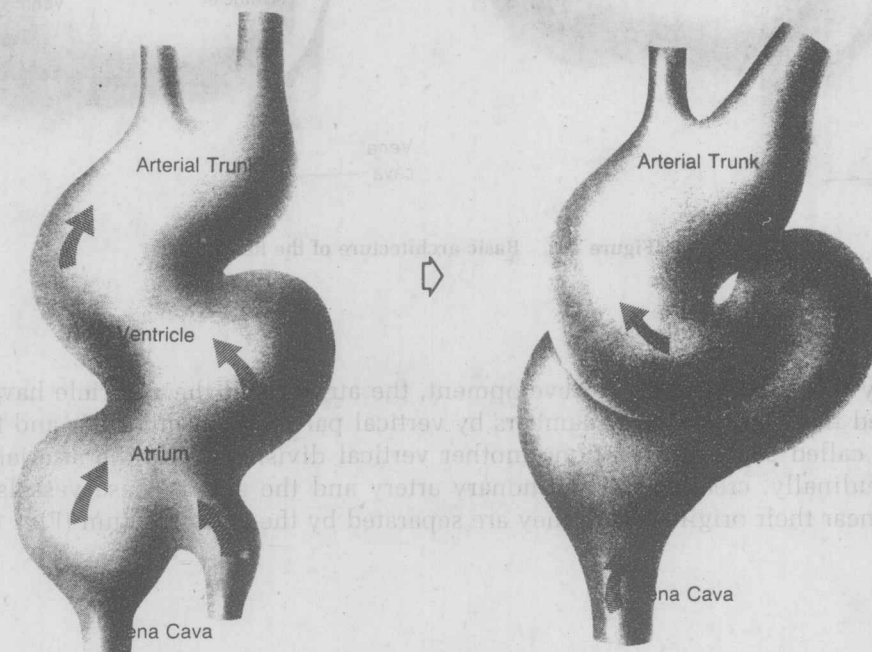


Figure 1-2. Convolutions of the cardiac tube.

The inflow trunk to the atria will be divided ultimately into the superior and inferior vena caval systems. The outflow trunk from the ventricles is the future aorta and pulmonary artery.

The ventricles develop a thick muscular wall; the thinner-walled atria balloon-out around the stem of the ventricles. Throughout their sequential development, the ventricles remain more or less central, with the atria forming chambers above the ventricles and around the arterial trunk (Fig. 1-3).

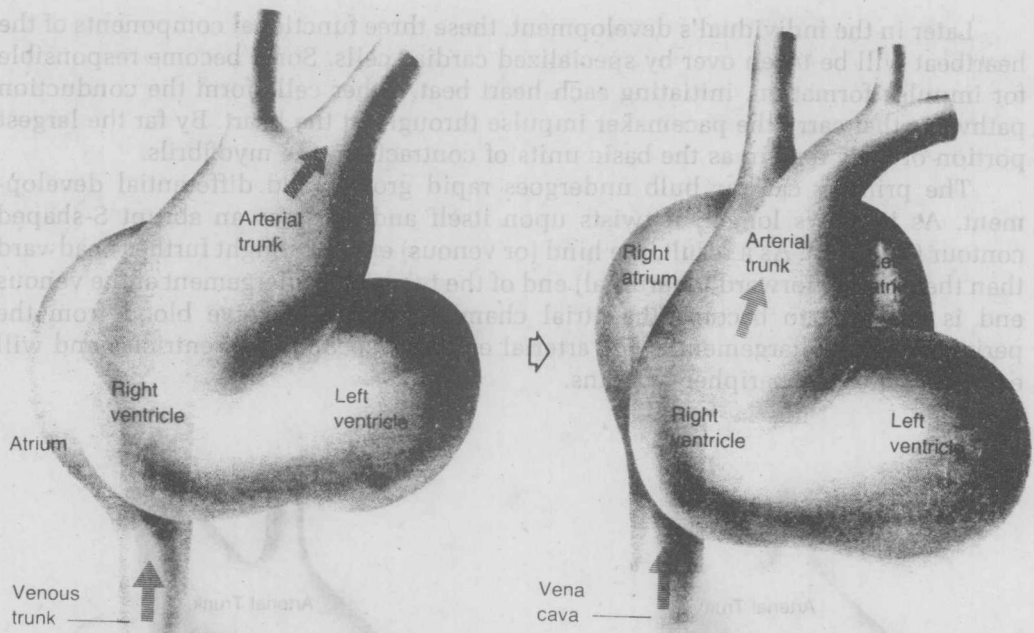


Figure 1-3. Basic architecture of the heart.

By the seventh week of development, the atrium and the ventricle have been divided into right and left chambers by vertical partitions of muscular and fibrous tissue called septa. In addition, another vertical division splits the arterial trunk longitudinally, creating the pulmonary artery and the aorta. These vessels criss-cross near their origin, where they are separated by the spiral septum (Fig. 1-4).

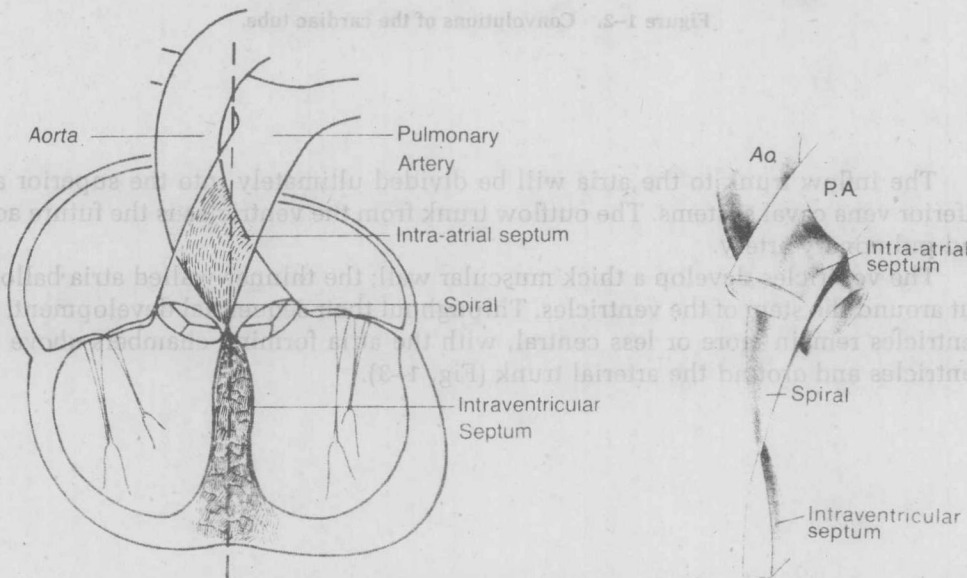


Figure 1-4. The cardiac septa: Vertical partitions.

Horizontal partitions of the heart are provided by four valves that permit flow of blood in one direction only. The **tricuspid** and **bicuspid** (or **mitral**) valves are interposed between the atrial and ventricular chambers. They are thin, fibrous, funnel-shaped structures with inner, moveable edges that are attached to the floor of the ventricles by fibrous strands, the chordae tendineae. Two valves at the origins of the pulmonary artery and the aorta are each composed of three leaflets, or cusps. These are referred to as the semilunar valves or, individually, as the **pulmonary** and **aortic** valves (Figs. 1-5 and 1-6).

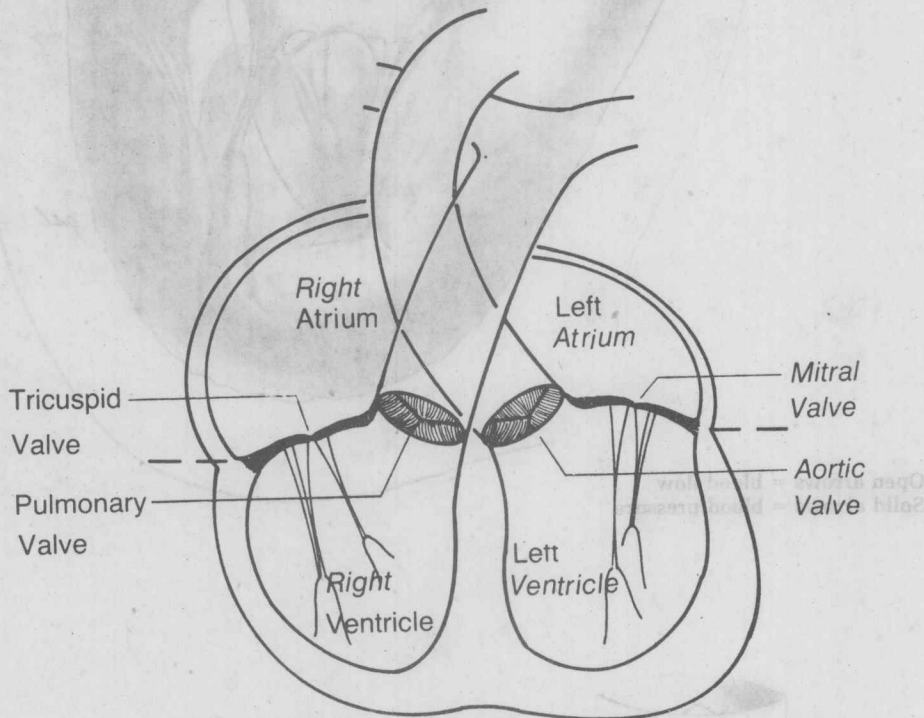
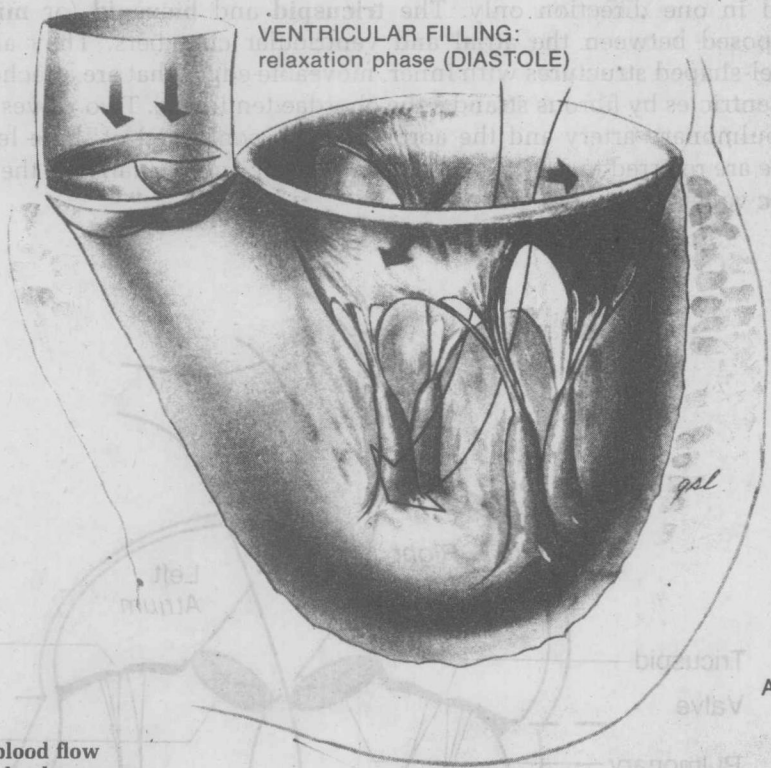


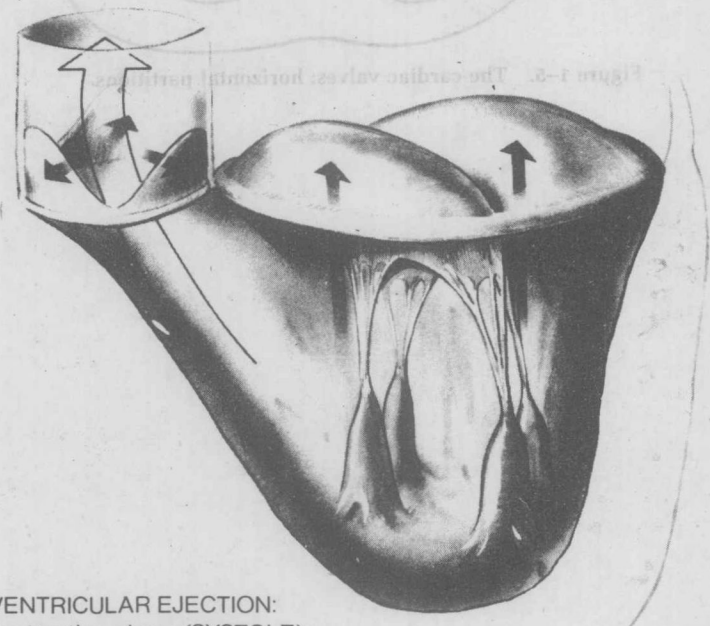
Figure 1-5. The cardiac valves: horizontal partitions.



Horizontal partitions of the heart are provided by four valves that permit flow of blood in one direction only. The tricuspid and mitral (bicuspid) valves are located between the right and left ventricles, respectively, and are attached to their fibrous rings by thin fibrous cords. The aortic and pulmonary valves are located at the origins of the aorta and pulmonary artery, respectively, and are attached to their leaflets, or cusps, by the pulmonary and aortic sinuses.



Open arrows = blood flow
Solid arrows = blood pressure



VENTRICULAR EJECTION:
contraction phase (SYSTOLE)

Figure 1-6.