PREFACE

This instructional guide was prepared for use with the DON JAKE SAUNDERS HEART MODEL from Medical Plastics Laboratory, Inc., of Gatesville, Texas.

The purpose of this guide is to provide a comprehensive introduction to the anatomy of the human heart for students of allied health professions as well as college and university students. One of the objectives is to provide an introduction to the gross structure of the human heart using the DON JAKE SAUNDERS HEART MODEL to illustrate the structural relationships. The other objective is to apply the knowledge of the anatomy of the heart to heart function. This guide is not intended to be a detailed or lengthy discussion of cardiac physiology.

The numbers in parentheses in the text of this guide refer to the key code numbers on the model. Two types of key code lists have been included: the first lists all coded structures in numerical order while the second has the numbers grouped according to location on the model.

The index lists all structures in alphabetical order. The bold faced numbers in the index refer to key code numbers and the regular type numbers refer to page numbers.

Recognition and thanks goes to Dr. Robert Daley at Ohio University, who has read the manuscript and has given the benefit of his constructive criticism.

For the illustrations, I am indebted to Mr. Danny Smith of Medical Plastics Laboratory, Inc. for his excellent work.

Last but certainly not least, special recognition must be given to the late DON JAKE SAUNDERS (1921-1976) of Medical Plastics Laboratory, Inc., who sculpted the heart model which bears his name. His expertise as a medical artist has lead to the development of a model which is second to none in accuracy and detail.

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INTRODUCTION

The heart is a muscular organ that acts as a double pump; the right side receives deoxygenated blood from the body and pumps it to the lungs while the left side receives the oxygenated blood from the lungs and pumps it to the rest of the body. The aorta acts as the receiving chambers of the heart and the ventricles as the pumping chambers.

The heart begins to beat toward the end of the first month of embryonic development and must continue to beat for the duration of the individual's life. In a lifetime of 70 years, the heart would beat over 2.5 billion times and would pump over 41 million gallons (158 million liters) of blood. If the heart were to stop for even a short time, irreversible changes would occur and death would quickly follow.

This remarkable muscular pump is about the size of the individual's clenched fist. The DON JAKE SAUNDERS HEART MODEL is approximately three times the size.

LOCATION

The heart is located in the central portion of the thorax called the mediastinum, which divides the thorax into left and right cavities (pleural cavities) that contain the lungs. It lies in the lower portion of the mediastinum behind and a little to the left of the sternum, and above the middle portion of the diaphragm. The upper portion of the mediastinum contains the large blood vessels (great vessels) entering and leaving the heart.

PERICARDIUM

A double-walled sac known as the pericardium encloses the heart and the roots of the great vessels. The outer fibrous layer (fibrous pericardium) is attached below to the diaphragm. Above it blends with the outer layers of the great vessels. The fibrous pericardium serves to limit the movement of the heart. The inner layer of the pericardium (serous pericardium), is a closed sac. It lines the fibrous pericardium (and is known as the parietal serous pericardium) and is reflected around the roots of the great vessels and becomes continuous with a layer (visceral serous pericardium) on the surface of the heart. Between the two layers is the pericardial cavity. A small quantity of serous pericardial fluid, secreted by the cells of the serous layers, fills the limited space of the cavity. This fluid permits frictionless movement of the heart when it beats.

The DON JAKE SAUNDERS HEART MODEL presents the anatomy of the heart with the fibrous and parietal serous pericardium removed.

![Fig. 1. Section through the thoracic cavity showing the organization of the serous and fibrous parts of the pericardium. The pericardial cavity lies between the parietal and visceral layers of the serous pericardium.](image-url)
EXTERNAL ANATOMY
When the model is sitting on its wooden base, it is in the correct anatomical position. In this position, the right border of the heart is formed by the right atrium, the left border is formed by the left ventricle (2) and a small part of the aorta of the left atrium (3), and the posterior surface of the heart is formed mainly by the left atrium (95) into which the pulmonary veins (50,51) open. The right atrium (94) also forms a small portion of this surface.

HEART WALLS
The walls of the heart consist of three layers: the inner "endocardium," the middle "myocardium" and the outer "epicardium."

The endocardium is a thin smooth glistering membrane which lines all of the chambers of the heart and is continuous with the inner lining of the blood vessels entering and leaving the heart. The endocardium also forms the walls of the heart which will be discussed in greater detail below.

The myocardium is the thickest layer of the heart wall consisting of cardiac muscle which is responsible for the heart's ability to contract and pump. A fibrous septum separates the musculature of the atria from the ventricles and surrounds the openings of the heart. The musculature of the atria is thin so the work required is minimal. The musculature of the ventricles is much thicker than that of the atria. The left ventricle is considerably thicker than the right since the left ventricle pumps the blood to the entire body while the right ventricle only pumps into the lungs. The musculature of the ventricles is made up of spiral layers of muscle which encircle the chamber. In this position they have their origin and insertion on the fibrous septum between the atria and ventricles. When the ventricles contract a wringing action results and the ventricular walls come together similar to a squeezing fist and exert pressure on the blood inside.

The outer layer of the heart, the epicardium, is the visceral serous pericardium which was discussed previously. This layer is merely attached to the myocardium except at the coronary and interventricular sulci where blood vessels and sizable deposits of fat intervene between the epicardium and myocardium.

CIRCULATION THROUGH THE HEART
The direction of blood flow through the heart is dictated by the blue and red arrows on the model. The heart receives blood by way of the veins and pumps it out through the arteries. Deoxygenated blood (blue arrows) from the upper part of the body, drains into the superior vena cava (8) and then into the right atrium (96). Blood from the lower part of the body enters the left atrium (94) through the inferior vena cava (90). From the right atrium (94), the blood passes through the tricuspid valve (93) into the right ventricle (1). When the ventricles contract, the blood is pumped through the pulmonic valve (66) into the pulmonary trunk (6) and then to the lungs by way of the pulmonary arteries (12,49). The pulmonary trunk (6) and arteries (12,49) transport deoxygenated blood and are, therefore, color coded in blue. Oxygenated blood (red arrows) from the lungs returns to the left atrium (95) of the heart through the pulmonary veins (50,51). After passing through the mitral valve (94) it flows into the left ventricle (2), the oxygenated blood is pumped through the aortic valve (80) to be distributed throughout the body by the aorta (3) and its branches (Figure 2).

BLOOD SUPPLY OF THE HEART
Coronary Arteries
An abundant supply of oxygenated blood reaches the muscle fibers of the myocardium by an extensive capillary network supplied by branches of the right and left coronary arteries (23,28).

At the origin of the aorta (6) just above the aortic valve (80), there are three coronary arteries which divide into smaller branches as they course along the inner surface of the aorta. The right coronary artery is given off immediately below the aortic valve and courses laterally along the underside of the heart. The left coronary artery is the first branch below the left atrium (94) and continues around the left atrium (95) to the left ventricle (2). The left coronary artery runs cephalad in a groove along the left margin of the heart. It supplies the left atrium, the left ventricle, the left atrial appendage, the left ventricular septum, and the anterior wall of the left ventricle. The left coronary artery gives off two branches, the anterior descending artery and the circumflex artery (29,4). The right coronary artery is entirely distinct from the left coronary artery. The left coronary artery gives rise to the left anterior descending artery (22,23,24) and the left circumflex artery (29,4,13). The right coronary artery gives rise to the right anterior descending artery (22,23,24) and the right circumflex artery (29,4,13).

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DON JAKE SAUNDERS HEART MODEL
Numerical Key Code

1. Right Atrium
2. Right Ventricle
3. Left Atrium
4. Left Ventricle
5. Aorta
6. Pulmonary Trunk
7. Tracheobronchial (Innominate) Vein
8. Superior Vena Cava
9. Tracheobronchial Trunk (Innominate Artery)
10. Common Carotid Artery
11. Subclavian Artery
12. Left Pulmonary Artery
13. Ligamentum arteriosum
14. Thyrocervical Trunk
15. External Jugular Vein
16. Subclavian Vein
17. Internal Jugular Vein
18. Internal Thoracic Artery
19. Internal Thoracic Vein
20. Inferior Vena Cava
21. Vertebral Artery
22. Vertebral Vein
23. Right Coronary Artery
24. Right Atrial Branch (Right Coronary Artery)
25. Superior Vena Cava (Medial Branch of Right Atrial Artery)
26. Right Marginal Artery (Right Coronary Artery)
27. Posterior Interventricular (Posterior Descending)
   Branch of Right Coronary Artery
28. Left Coronary Artery
29. Circumflex Branch (Left Coronary Artery)
30. Anterior Interventricular (Anterior Descending)
   Branch of Left Coronary Artery
30A. Diaphragmatic Branch of Anterior
     Interventricular Artery
31. Great Cardiac Vein
32. Anterior Cardiac Veins
33. Small Cardiac Vein
34. Coronary Sinus
35. Posterior Vein of Left Ventricle
36. Oblique Vein of Left Atrium
37. Middle Cardiac Vein
38. Left Vagus Nerve
39. Right Vagus Nerve
40. Recurrent Laryngeal Nerve
   (Branch of Left Vagus)
41. Left Vagal Cardiac Nerves
42. Left Sympathetic Cardiac Nerves
43. Right Sympathetic Cardiac Nerves
44. Thoracic Duct
45. Esophagus
46. Trachea
47. Right Branches
48. Left Branches
49. Right Pulmonary Artery
50. Left Pulmonary Veins
51. Right Pulmonary Veins
52. Azygos Vein
53. Superior Intercostal Vein
54. Posterior Intercostal Arteries
55. Tracheal Lymph Nodes
56. Inferior Tracheobronchial Lymph Nodes
57. Internal Jugular Lymph Nodes
58. Anterior Mediastinal Lymph Nodes
59. Azygous Bundle of Hilts
60. Inferior Vena Cava
61. Suprarenal Crescent
62. Septal Band
63. Mediastinal Band
64. Tracheal Cameme
65. Coronary Arteries (Infundibulum)
66. Pulmonary Valve
67. Right Bundle Branch
68. Posterior Papillary Muscle
69. Anterior Papillary Muscle
70. Septal (Medial) Papillary Muscle
71. Pyramidal Band
72. Anterior Cusp - Tricuspid Valve
73. Septal (Medial) Cusp - Tricuspid Valve
74. Posterior Cusp - Tricuspid Valve
75. Chordae Tendineae
76. Anterior Papillary Muscle
77. Posterior Papillary Muscle
78. Anterior Cusp - Bicuspid Valve
79. Posterior Cusp - Bicuspid Valve
80. Aortic Valve
81. Aorta Graft
82. Valve of Inferior Vena Cava
83. Office of Coronary Sinus
84. Crista terminalis
85. Inferior Septum
86. Sinocaval (SA) Node
87. Bachmann's Bundle
88. Posterior Internodal Tract
89. Pectinate Muscle
90. Anterior Internodal Tract
91. Middle Internodal Tract
92. Valve of Foramen Ovale
93. Tricuspid Valve
94. Bicuspid Mitral Valve
95. Left Atrium
96. Right Atrium
97. Muscular Interventricular Septum
98. Membranous Septum (Interventricular Part)
99. Membranous Septum (Atrioventricular Part)
100. Atrioventricular (AV) Node
101. Anterior Cusp - Pulmonic Valve
102. Right Cusp - Pulmonic Valve
103. Left Cusp - Pulmonic Valve
104. Right Coronary Cusp - Aortic Valve
105. Left Coronary Cusp - Aortic Valve
106. Posterior (Non-Coronary) Cusp - Aortic Valve
107. Left Bundle Branch
108. Purkinje Fibers

Color Code
Arteries .......... Red
Veins .......... Blue
Lymphatics .......... Green
Nerves .......... Off-White

Fig. 2. Scheme of the systemic and pulmonary circulation. Oxygenated blood is shown in dot pattern; deoxygenated blood in line shading. The arrows indicate the direction of blood flow.
part of the sulcus together with the small cardiac vein (33) and anastomoses with the circumflex branch of the left coronary artery (29). Three major branches of the right coronary artery (23) are shown on the model. The first branch, one of the anterior right atrial branches (24), originates near the apex and ascends in the anterior interventricular sulcus to reach the coronary (atrioventricular) sulcus. It follows this sulcus to the left and around to the back of the heart where it enters the beginning of the coronary sinus (34). In its course, the great cardiac vein accompanies the anterior interventricular artery (30) and the circumflex branch of the left coronary artery (29). The second major branch of the coronary artery is the right marginal artery (26) which descends along the right border of the heart and supplies the myocardium of the right ventricle (1). As the right coronary artery passes the posterior interventricular sulcus, it gives off the posterior interventricular (or posterior descending) artery (27) which supplies the adjacent portions of the myocardium of both ventricles as well as part of the interventricular septum (97).

The left coronary artery (28) arises from the left atrioventricular sulcus (105) and passes between the pulmonary trunk (42) and the outflow of the left atrium (40) to reach the coronary (atrioventricular) sulcus. Upon reaching the sulcus, the left coronary artery (28) branches into the anterior interventricular (or anterior descending) artery (30) and the circumflex artery (29). The anterior interventricular artery (30) descends in the anterior interventricular sulcus and in many subjects turns around the apex of the heart and runs a variable distance in the posterior interventricular sulcus. This artery has a branch (30a) which supplies the myocardium of both ventricles and part of the interventricular septum (97) and also anastomoses with the posterior interventricular artery (27). The circumflex branch (29) is the continuation of the left coronary artery (28) in the coronary sulcus. If anastomoses with the posterior interventricular artery (27) in the sulcus on the posterior aspect of the heart, branches off of the circumflex artery supply the upper portion of the left ventricle (23) and the adjacent left atrium. Left marginal branches of the circumflex (not numbered on the model) extend along the left border of the heart.

The anastomoses between the branches of the coronary arteries are at the level of the arteries. These small branches of the coronary arteries are functionally and arteries, since the anastomoses through them are not adequate to maintain sufficient collateral circulation if a large branch of a coronary artery were to suddenly become obstructed. If, on the other hand, the obstruction developed gradually, the small vessels of the anastomoses could enlarge to provide some measure of relief to the affected area.

Coronary Veins

The capillary bed of the myocardium is supplied with blood from the coronary arteries and is drained by the coronary veins. These veins follow the arteries in the coronary arteries (left anterior and interventricular sulci) and are usually superficial to the arteries. Most of the veins drain into a wide venous channel, the coronary sinus (34), located in the posterior portion of the coronary sulcus. The coronary sinus (34) drains into the right atrium (96) between the opening of the inferior vena cava and the tricuspid valve (see number 83 inside the right coronary area).

The main tributaries of the coronary sinus are:
1. The great cardiac vein (33) which begins near the apex and ascends in the anterior interventricular sulcus to reach the coronary (atrioventricular) sulcus. It follows this sulcus to the left and around to the back of the heart where it enters the beginning of the coronary sinus (34). It contains the great cardiac vein accompanying the anterior interventricular artery (30) and the circumflex branch of the left coronary artery (29).
2. The middle cardiac vein (37) begins near the apex and ascends in the posterior interventricular sulcus and drains into the coronary sinus (34) near its termination. The middle cardiac vein parallels the posterior interventricular artery (27).
3. The small cardiac vein (33) usually begins as the right marginal vein. After reaching the coronary sinus it turns to the right following the sulcus to the back of the heart where it enters the coronary sinus (34) near its termination. The small cardiac vein (33) accompanies at first the right marginal artery (30) and then the right coronary artery (23) after it reaches the coronary (atrioventricular) sulcus.
4. The posterior vein of the left ventricle (36) ascends along the diaphragmatic surface and left margin of the heart and drains into the left end of the coronary sinus (34) near its beginning.
5. The oblique vein of the left atrium (34) descends obliquely over the left atrium and drains into the left end of the coronary sinus (34).

The anterior cardiac veins (32) are small vessels which ascend on the anterior wall of the right atrium (1) cross the coronary sulcus above the right coronary artery (23) and open directly into the right atrium. The venae cordis minimae (smallest cardia veins at thebesian veins are minute veins in the myocardium which open directly into the heart chambers. These veins are too small to be shown on the model.

INTERNAL FEATURES OF THE HEART

With the four doors of the DON JAKE SAUNDERS HEART MODEL open, note the thickness of the muscular walls of each chamber: the atria have considerably thinner walls than the ventricles. This difference reflects the fact that the atria act as receiving chambers of the heart and the ventricles as the pumping chambers.

Each of the four chambers has its own characteristic appearance, structure, and related vessels.

Right Atrium

The thin-walled right atrium receives deoxygenated blood from the body by way of the vena cava (85) and from the heart itself by way of the coronary sinus (34) and anterior cardiac veins (32). The vena cavae are in line with one another; the superior vena cava drains into the right atrium vertically from above while the inferior vena cava (40) enters it vertically from below. The coronary sinus (34)
drains into the right atrium just to the left of the opening of the inferior vena cava (see 83 in the right atrium).

The orifice of the superior vena cava has no valve.

The orifice of the inferior vena cava has a rudimentary valve, the valve of the inferior vena cava (or Eustachian valve) (82), formed by a crescentic fold on the anterior margin of the orifice. This valve is more prominent during intrauterine life where it serves to direct the blood from the inferior vena cava into the left atrium through an opening, the foramen ovale, in the interatrial septum. In this manner, blood bypasses the non-functioning lungs. The circulation of blood through the fetal heart is covered in more detail below. The valve of the inferior vena cava (82) has no known function in the adult heart. The foramen ovale normally closes shortly after birth and becomes the fossa ovalis (81), and oval depression in the lower part of the septum wall. The membranous part of the atrioventricular septum (99) extends slightly above the attachment of the septal (medial) cusp (77) of the tricuspid valve where it forms part of the medial wall of the right atrium. More will be said about the interventricular septum later.

The right atrium can be divided into two parts: the posterior part into which the superior and inferior vena cava enter has smooth walls and is, developmentally, a continuation of these vessels. The anterior part of the right atrium is the original embryonic right atrium and its walls consist of parallel muscle ridges called pectinate muscles (89). The two parts of the right atrium are separated from one another by a smooth muscle ridge, the crista terminale (84). The pectinate muscles (89) run forward from the crista terminale (84) across the lateral and anterior walls of the atrium, angling toward the tricuspid valve (93). The upper portion of the crista contains a conical muscular outpouching called the atrial (83). Externally the atrial (83) lies in front of the tract of the sinus (95) and covers the first portion of the right coronary artery (22). Internally the wall of the atrium is covered with pectinate muscles (89). A somewhat larger pectinate muscle, the lusoria sagittalis (85), originates from the crista terminale and extends into the atrial (83).

Two important structures associated with the conduction system of the heart are located in the wall of the right atrium. The sinoatrial (SA) node (86) is located at the upper end of the crista terminalis (84) at the junction of the atrium proper and the superior vena cava (8). In an actual specimen, the node would not be visible since it is located within the myoendocardium trabeculated impolus which cause the heart to contract rhythmically, originate from the SA node which is often referred to as the “pacemaker.” The sinus impulse spreads to the right atrium directly from the SA node. Tracts of modified cardiac muscle cells (87, 88, 89, 91) carry the sinus impulse to the left atrium and to the atrioventricular (AV) node (100). Bachmann’s bundle (87) transmits these impulses to the left ventricle while three internodal tracts (88, 91, 99) transmit them to the AV node (100) which is located in the interatrial septum just above the orifice of the coronary sinus (83). The atrioventricular bundle (of His) (97) transmits the impulse from the AV node through the fibrous atrioventricular septum into the musculature of the interventricular septum (97). The conduction system of the heart is covered in more detail below.

Right Ventricle

The outer wall of the right ventricle is much thicker than the walls of the aorta but thinner than those of the left ventricle. The right ventricle has a crescent-shaped chamber due to the thick interventricular septum (97) bulging into its cavity.

Functionally the right ventricle can be divided into inflow and outflow portions. The inflow portion consists of the right atrioventricular (or tricuspid) valve (93) and the trabeculated (64) apical walls of the ventricle. The outflow portion, the conus arteriosus or infundibulum (65), has relatively smooth walls and leads upward to the pulmonary valve (66). The two divisions of the right ventricle are partially separated from one another by muscular ridges: the pectal band (76), the supraventricular crest (64), and the septal band (63).

Blood flows from the right atrium into the right ventricle through the right atrioventricular orifice. This orifice is anastomosed by a fibrous ring which makes up part of the atrioventricular septum that completely separates the myocardium of the atria from that of the ventricles. The orifice is guarded by the tricuspid (right atrioventricular) valve (93) so named because of the three somewhat triangular leaflets or cusps (72, 73, 74) which make up the valve. The cusps are named according to their positions: anterior (73), septal (72), and posterior (74). The bases of the valves are attached to the fibrous ring around the orifice while the apexes of each valve extends into the ventricle. Some tendinous cords, the chordae tendineae (75), extend from the undersides (ventricular sides) of the cusps to cone-shaped muscular projections known as papillary muscles. The anterior papillary muscle (69) is the largest and receives chordae tendineae from the anterior (72) and posterior (74) cusps. The posterior papillary muscle (68) receives chordae tendineae from the posterior (74) and septal (73) cusps. The septal (or medial) papillary muscle (79), located approximately where the crest (64) meets the septal band (62) receives chordae tendineae from the anterior (72) and septal (73) cusps. Some chordae tendineae from the septal cusp attach directly to the septum. Papillary muscles are often represented by two or more parts.

In addition to the papillary muscles, the anterior and inferior walls of the inflow portion of the right ventricle are lined with irregular muscular ridges and bulges called trabeculated carneae (86). A muscular septum, the septomarginal trabecula or moderator band (65) extends from the interventricular septum to the anterior wall where it joins the base of the anterior papillary muscle (69). It was named “moderator band” because at one time it was thought to prevent overdistension of the ventricle when filling with blood. The moderator band (65) contains part of the right bundle branch (67) of the atrioventricular bundle (of His) (97).
ventricular septum (97) toward the posterior margin of the membranous part of the septum (99). From this point, the right bundle branch (57) courses toward the ventricular apex beneath the endocardium. Divi-
sions of the right bundle reach the anterior ventricu-
lar wall and the base of the anterior papillary muscle (61) through the septomarginal trabecula (moderator-
ator band) (63). The divisions break up into a plexus of Purkinje fibers (108), which pass beneath the endo-
cardium to the greater part of the right ventricle
where they end by becoming continuous with the myo-
cardial fibers.

The tunnel-shaped outflow portion of the right ven-
tricle, known as the conus arteriosus or infundibulum
(65) is in the superior part of the right ventricle. It has
smooth walls and is continuous with the pulmonary
trunk (6). The pulmonary valve (64) separates the in-
fundibulum from the pulmonary trunk. This valve con-
sists of three semilunar cusps (101, 102, 103) attached
to the base of the wall of the pulmonary trunk. The
pocket-like cusps are designated anterior (101), right
(102) and left (103).

Left Atrium

Oxygenated blood from the lungs enters the left
atrium (95) of the heart through four pulmonary veins
(50, 54). The orifices of these veins are not guarded
by valves. The inner walls of the left atrium are smooth
except in the auricle (4) where parallel ridges called
pectinate muscles (89) are present. A semilunar
depression on the septal wall of the left ventricle
marks the location of the fossa ovalis (81) of the left
atrium. Interior to this depression is a crescentic
ridge, the valve of the foramen ovale (92), which is
a remnant of the septum that closed the foramen
ovale at the time of birth.

Left Ventricle

The walls of the left ventricle are approximately
two to three times the thickness of the right ventricle.
The left ventricular cavity is somewhat conical in
shape with the apex of the cone representing the
apex of the heart. Most of the ventricular wall is
covered with a fine network of irregular muscular
ridges and bridges called trabeculae carneae (64)
which are especially dense at the apex. The upper
anterior part of the ventricle leading to the aortic
valve (80) is relatively smooth. Two large papillary
muscles arise from the anterior (76) and posterior
(77) walls and are named accordingly. Chordae tendi-
necae (73) extend from the tips of the papillary mus-
cles to the ventricular surface (underside) of the cusps of the left atrioventricular valve (78, 79). The
valve is similar in construction and function to that
of the tricuspid valve (93), except that it has only two
cups (bicuspid). The bicuspid valve (94) is commonly
referred to as the mitral valve because of the resem-
b lance of its two cusps to a bishop's mitre. The ante-
rior cup (78) is located between the aortic and left
atrioventricular orifices. The posterior cup (79) is
located behind and to the left of the orifice. The papil-
lar muscles (76, 77) are located below the commis-
sures of the valve and chordae tendineae (75) ex-
tend from each muscle to the two cusps.

The left bundle branch (107) of the atrioventricular
bundle (84) descends immediately beneath the endo-
docardium as a broad band which divides into a
small anterior and large posterior division. The two
divisions divide into lesser divisions which in turn
break up into a plexus of Purkinje fibers (108) in the
subendocardial connective tissue (74) and papillary
muscles (76, 77).

The aortic orifice is guarded by the aortic sim-
ilunar valve (75) composed of three papillary
valves: a right cup (104), a left cup (105) and a posterior
cup (106). The structure and mode of attachment of
these cusps are similar to those of the mitral valve
(87) except that they are larger, thicker and stronger.
On the aortic side of the valve, behind each cup,
there is a pouch-like dilatation known as an aortic
sinus. The left coronary artery (28) arises from behind
the left cup and the right coronary artery from behind
the right cup. The left and right cups are often
referred to as "coronary" cusps. The posterior
cup (106) is not associated with the origin of a
coronary artery and is referred to as the "noncoro-
nary" cup.

Interventricular Septum

The left and right ventricles are separated from
one another by the interventricular septum. The sep-
tum bulges into the cavity of the right ventricle.
On the surface of the heart, the anterior and posterior
interventricular grooves or sulci correspond with the
margins of the septum. Most of the septum is thick
and muscular (muscular interventricular septum (97),
but its upper part, thin and fibrous (membranous
septum (98, 99). On the left side, the membranous
septum (98) lies below the junction of the right (104)
and posterior (106) cusps of the aortic valve. On the
right side, the membranous septum is crossed by the
attached border of the septal cup (73) of the tricus-
pid valve, which divides it into anterior and posterior
parts. The anterior part separates the two ventricles
from each other (membranous interventricular sep-
tum (98). The posterior part separates the right atria
from the left ventricle just below the aortic valve
(membranous aorticentricular septum (99)).

During embryonic development, the membranous
portion of the septum grows downward from the
fibrous skeleton of the heart which separates the
atria from the ventricles. Failure of the membranous
septum to fuse with the muscular septum would result
in an interventricular septal defect or a patent inter-
ventricular septum. Such a condition would result in
leakage of oxygenated blood from the high pres-
sured left ventricle into the right ventricle.

Heart Valves

The fibrous septum which separates the musculature of the atria from that of the ventricles is referred to as the fibrous skeleton of the heart and corresponds roughly to the plane of the atrioven-
tricular groove on the surface of the heart. When visualized with the atria removed, the fibrous ske-
leton appears as four fused rings of connective tissue, one for each heart valve. These rings form bases to
which the heart valves are attached. The cusps of each valve consist of a reflection of the endo-
cardium strengthened by intervening layers of
fibrous tissue.
clavian artery and runs downward, behind the brachiocephalic veins. Below the level of the first rib, the artery descends vertically about 1 cm lateral to the margin of the sternum where it supplies the anterior wall of the body from the clavicle to the umbilicus. The thyrocervical trunk (14) is a short thick stem which divides immediately into three main branches which supply the thyroid gland (inferior thyroid artery) and the muscles of the shoulder and scalene (superficial and transverse cervical arteries).

The diameter of the aortic arch is about equal to that of the ascending aorta until after the left subclavian artery branches off. At this point the diameter narrows to about 2 cm.

The descending portion of the thoracic aorta is continuous with the aortic arch, and at first it lies to the left of the vertebral column. As it descends it approaches the medial plane and terminates by passing through the diaphragm in front of the vertebral column. The posterior intercostal arteries (54) are branches from the posterior surface of the descending aorta that are distributed to the intercostal muscles and the posterior and lateral thoracic wall.

THE SUPERIOR VENA CAVA AND ITS BRANCHES

Venous blood from the head and neck, the upper limbs, and thoracic wall returns to the heart through the superior vena cava (8). This large vessel is formed by the union of the right brachiocephalic (innominate) veins (7) at the level of the first costal cartilage. This union is to the right side of the ascending aorta (5) and ends in the upper part of the right atrium. The ayzygos vein (52), which receives venous blood from the posterior blood from the posterior and lateral thoracic wall, enters the superior vena cava just above the structures at the root of the right lung (bronchus (47), right pulmonary artery (49) and vein (51)).

The brachiocephalic veins (7) are formed in the base of the neck by the union of the internal jugular (17) and subclavian (16) veins. The right brachiocephalic vein is short and descends almost vertically while the left is considerably longer and runs downward and to the right.

The internal jugular vein (17) has its origin at the base of the skull and receives blood from the brain, face, and neck. The subclavian vein (16) accompanies the subclavian artery (11); the two trunks branch from the axillary vein which drains the upper limbs. The left subclavian vein (15) receives tributaries from the scalp, face and neck and joins the subclavian vein (16) just before the internal jugular (17) to form the brachiocephalic vein (7).

Each brachiocephalic vein receives a vertebral (22) and internal thoracic (19) vein. The vertebral vein (22) opens into the upper and posterior part of the brachiocephalic vein (7). The internal thoracic vein (19) accompanies the artery (18) and receives venous blood from the anterior thoracic body wall.

In addition to the vertebral and internal thoracic veins, the left brachiocephalic vein receives tributaries which drain the second and third intercostal spaces, the superior intercostal vein (63), and the thyroid gland, the inferior thyroid vein (60).

LYMPHATIC SYSTEM

The lymphatic system provides for drainage of tissue fluid back into the venous system and also provides the main immune mechanism for the body. It is beyond the scope of this book to present a detailed discussion of the lymphatic system, however, since it is considered a major component in disease processes and numerous lymph nodes, a brief discussion is appropriate.

Cells of the body get their nutritive material from tissue fluid that resembles plasma in chemical composition. This material passes through the blood capillaries into the tissue fluid. Waste products from the cells pass into the tissue fluid and most readily re-enter the capillaries, however, the large protein molecules do not. It is the function of the lymphatic system to absorb these molecules and return them to the blood vascular system. Only a small part of the lymphatic system is demonstrated on the DON JAKE SAUNDERS HEART MODEL and it is shown in green.

The tissue fluid is called lymph once it has entered the lymphatic system. This system begins in a network of lymph capillaries which collect the tissue fluids. The capillaries come together to form larger and larger lymphatic vessels which eventually reach the regional lymph nodes. Lymphatic vessels carry the lymph one from lymph node to another. The lymph vessels join together forming lymphatic trunks which in turn join to form lymphatic ducts. The ducts empty into the venous system at the junction of the internal jugular vein and subclavian vein.

The thoracic duct (44) drains the thoracic wall and the body below the diaphragm. This duct originates in the abdomen in a dilated structure called the cisterna chyli. In the thorax it is posterior to the esophagus (45) until it reaches the upper part of the thorax where it joins the left. In the base of the neck it turns laterally to the left behind the common carotid artery (46) and internal jugular vein (17). It enters the venous system in the angle between the left internal jugular vein (17) and the left subclavian vein (16).

Lymphatic vessels from the upper part of the body usually join the thoracic duct (44) just before it joins the venous system. The lymphatic vessels from the upper right side drain into the right lymphatic ducts, which join the venous system in the common location on the right side.

Lymph nodes in the thoracic cavity and the base of the neck are very abundant in number as shown on the DON JAKE SAUNDERS HEART MODEL.

Tracheobronchial lymph nodes are located in the region of the tracheobronchial bifurcation. The inferior tracheobronchial nodes (37) are located in the angle between the trachea below the bifurcation. The superior tracheobronchial nodes which are not numbered on the model, are in the angle between the trachea (44) and the tracheobronchial bifurcation. These nodes are responsible for the lymphatic drainage from the trachea, bronchi, and lungs. Some lymph nodes tend to the septal cuff (73) arise from the septal cuff. The bileacipal or aortic valve (40) consists of anterior (78) and posterior (79) cuffs which are larger, thicker and stronger than those of the tricuspid valve. The anterior cuff (78) is located anterior to the right side of the atrioventricular orifice. The posterior cuff (79) is located posterior and to the left of the atrioventricular orifice. There are usually two papillary muscles in the left ventricle, an anterior (75) located on the anterior wall and a posterior (77) on the posterior (inferior) wall. These papillary muscles occasionally show doubling as demonstrated by the posterior papillary muscle (77) in the DON JAKE SAUNDERS HEART MODEL. Chordae tendineae (75) go to both cuffs from each papillary muscle.

Blood passing through the atrioventricular orifices into the ventricles, pushes the cusps aside. When the ventricles contract, the back pressure of the blood forces the cusps together to close the orifice. The papillary muscles contract with the ventricles and the chordae tendineae are tightened thus holding the cusps in position and preventing their being expelled into the atria. Dysfunction of a papillary muscle or rupture of a chordae tendineae may affect the support of the valve cusps and produce regurgitation of blood into the atrium. Closure of the atrioventricular valves causes the first heart sound: the "lub" or "lub-dub.

Aortic and Pulmonic Valves

The pulmonic (66) and aortic (80) valves were referred to as "semilunar" because each valve has three semilunar pocket like cuffs formed by reflections of the endothelial lining of the heart (Figure 3). The cuffs are of approximately equal size. Their convex outer borders are attached to ends of
Heart Sounds

During the cardiac cycle, sounds which may be heard and/or detected using the cardiovascular system. For descriptive purposes the thoracic portion of the cardiovascular system is divided into ascending aorta, the aortic arch, and the descending aorta.

The ascending aorta begins as a continuation of the left ventricle where it is continuous the pulmonary trunk (5) and by the aortic arch (8). The ascending aorta is divided into three branches: the left subclavian (6), the left common carotid (7), and the right subclavian (10).

The left common carotid artery (10) is the next branch and arises from the highest part of the arch. It then divides into the left common carotid and the right subclavian arteries (10). The left common carotid artery (10) supplies blood to the head and neck. Although the left and right common carotid and subclavian arteries arise differently, they have the same distribution on the two sides of the body. The common carotid arteries course upward in the neck and then divide into the internal and external carotid arteries shown on the model, the common carotid gives off branches which are the major vascular supply to the head and neck.

The subclavian arteries course upward and laterally to supply the upper part of the upper extremity. They then run laterally and downward over the first rib. At the lateral border of the first rib, the subclavian arteries become the axillary arteries and the major vascular supply to the upper limb. The origins of the internal and external carotid arteries are shown on the model. These arteries are located at the transverse foramina of the first cervical vertebra and are also on the middle of the brain. In its course it gives branches to some neck muscles, vertebrae, the spinal cord and the brain. The internal thoracic artery (16) arises from the internal part of the subclavian artery.
ELECTROCARDIOGRAPHY

The electrical impulse which passes through the cardiac conduction system of the heart, spreads to other tissues surrounding the heart and very weak currents are transmitted to the surface of the body. By placing electrodes small metal plates on the skin on any two sides of the heart, the impulses generated during each beat can be picked up, amplified and recorded on an instrument called an electrocardiograph. The recorded impulse can be displayed on a pen recorder or a cathode ray oscilloscope. The record so produced is called an electrocardiogram and abbreviated ECG (or KG).

The ECG is a graph of voltage variations plotted against time. Figure 6 illustrates a typical normal ECG recorded with the electrodes on the left and right wrists (lead I). The vertical lines indicate time in seconds and horizontal lines, amplitude in millivolts. The "F" wave is caused by the impulse spreading over the atria. The "QRS complex" corresponds to the impulse passing through the ventricles. The "T" wave is caused by the reestablishment of the original electrical properties of the ventricular muscle cells.

The shape of the waves depends on the site of the recording electrodes. The particular arrangement of each two electrodes is termed a "lead." Routine clinical electrocardiography consists of recording from twelve leads: three standard limb leads (I,II,III), six precordial or chest leads (V1, V2, etc.) and three unipolar or augmented, limb leads (AVL, AVF, AVV). Since heart disease is generally accompanied by abnormal electrical events, the electrocardiogram has developed into one of the most useful tools in medicine.

SYSTOLE AND DIASTOLE

The period during the cardiac cycle when the ventricles are contracting is termed "systole," and the period of ventricular relaxation is termed "diastole" (Figure 6). The periods of systole and diastole can be noted from the electrocardiogram or from the heart sounds. Systole begins with the QRS wave and ends with the T wave or it begins with the first heart sound and ends with the second. Diastole begins with the end of the T wave and lasts until the onset of the QRS wave, or it begins with the second heart sound and ends with the first.

The parasympathetic innervation of the heart is from branches of the tenth cranial nerve, the vagus nerve (X), to the heart. Cardiac branches from the right vagus (39) pass primarily to the deep portions of the heart whereas the left vagus (40) supplies the superficial portions of the heart. The left recurrent laryngeal nerve (145) branches from the left vagus (38) as it crosses the aortic arch. It hooks under the aortic arch behind the ligamentum arteriosum (13) and descends into the neck to innervate part of the larynx. Numerous branches from the left recurrent laryngeal nerve (40) are given off to the cardiac plexus under the arch of the aorta. The parasympathetic nerves pass through the cardiac plexus and follow the pulmonary trunk and enter the heart. These nerves follow the coronary arteries which they innervate, to supply the SA and AV nodes and the atria. It is generally felt that the vagal fibers do not innervate the ventricular myocardium.

NERVATION OF THE HEART

Modification of the intrinsic rhythm of the heart relates to the change in physiological needs of the body is produced by the cardiac nerves of the autonomic nervous system. The sympathetic division of this system increases the heart rate and force of contraction and dilates the coronary arteries to make available increased amounts of oxygen and nutrients. The parasympathetic division, on the other hand, slows the heart rate, reduces the force of contraction and constricts the coronary vessels.

Sympathetic cardiac nerves (42, 43) from sympathetic ganglia in the neck and upper thorax, converge in the area between the aortic arch and the point where the aorta divides to form the right (47) and the left (48) brachial. Here the nerves form a network of interlacing nerves known as the cardiac plexus. The sympathetic nerves pass through the cardiac plexus, along the pulmonary trunk and the aorta to reach the coronary vessels and follow these throughout the heart. In addition to innervating the coronary arteries, the sympathetic nerves innervate both the SA and AV (109) nodes, as well as the myocardium of the atria and ventricles.

CIRCULATORY CHANGES AT BIRTH

At birth or soon afterwards there are a number of changes which occur in the circulatory organization (Figure 5). After respiration begins, the umbilical cord is ligated and the placental circulation is cut off. The umbilical vessels cease in their function and gradually becomes fibrous structures, the abdominal portion of the umbilical arteries become the lateral umbilical ligaments, and umbilical vein becomes the ligamentum teres, hepatis from the liver. The ductus venosus between the umbilical vein and the inferior vena cava closes and forms the ligamentum venosum of the liver.

When respiration begins, the lungs expand, decreasing their resistance to blood flow and thus increasing the amount of blood flowing through them. At this time, the ductus arteriosus closes rapidly, thus diverting all of the blood that enters the pulmonary trunk through the lungs. The ductus arteriosus obliterates to become the ligamentum arteriosum (13). The pressure in the left atrium becomes equal to that in the right and the foramen ovale of the foramen ovale (92) closes and fuses with the interatrial wall. The fossa ovalis (81) of the adult heart indicates the former location of the foramen ovale.

Failure of the foramen ovale or the ductus arteriosus to close allows deoxygenated blood to mix with oxygenated and results in a "blue baby." The severity of the condition depends on the site of the opening; when it is large, it is incompatible with life. Modern surgical techniques can be employed to correct these conditions.

Fig. 6. The cardiac cycle correlated with ECG and heart sounds.
Fig. 4. Circulation of blood in the fetus. The arrows indicate the direction of blood flow. Note the flow through the heart and compare with the flow after birth shown in Figure 5.

Fig. 5. Circulation of blood after birth. Areas where changes occurred at time of, or shortly after, birth are indicated.