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Frederick F. Waugh

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## Physiology of the Heart

Frederick F. Waugh\*

THE HEART HAS BEEN THE SUBJECT of much literature, ranging from rudimentary studies found in elementary biology texts, to obtuse technical theses of specific aspects of the many functions and disorders of this organ. Due to the magnitude of the subject, this article will be restricted to a very perfunctory treatment of the subject, which concerns the function of the heart and the various disorders affecting it.

In discussing the physiological aspects of the heart and its disorders, the following are some of the important terms:

*Angina Pectoris*—Pain in the region of the heart, often of an agonizing type. *Angina Pectoris* is not a disease, but is only a symptom which may be functional or organic.<sup>1</sup>

*Atherosclerosis*—A fatty degeneration of the walls of arteries.<sup>2</sup>

*Arteriosclerosis*—A degeneration and hardening of the walls of arteries, capillaries or veins, due to chronic inflammation resulting in fibrous formation.<sup>3</sup>

*Arrhythmia*—Absence of rhythm.<sup>4</sup>

*Bradycardia*—Slow heart action.<sup>5</sup>

*Dyspnea*—Labored or difficult breathing, usually accompanied by pain.<sup>6</sup>

*Edema*—Condition of body tissues containing grossly abnormal amounts of fluid.<sup>7</sup>

*Embolism*—Obstruction of a blood vessel by a foreign substance, instead of a blood clot.<sup>8</sup>

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\* B.S. in Business Administration, Bowling Green State University, Third-year student at Cleveland-Marshall Law School.

<sup>1</sup> Goldstein and Shabat, *Medical Trial Technique*, 367 (1942).

<sup>2</sup> Taber, *Cyclopedic Medical Dictionary*, A-104 (4th Ed. 1942).

<sup>3</sup> Id., at A-93.

<sup>4</sup> Id. at A-92.

<sup>5</sup> Id. at B-50.

<sup>6</sup> Id., at D-61.

<sup>7</sup> Id., at E-8.

<sup>8</sup> Id., at E-17.

*Infarct*—A type of gangrene (death of tissue) due to a thrombosis, usually found in the heart and lungs, wherein the dead tissue assumes a triangular, wedge-shaped appearance. When it occurs in the heart, it is called a cardiac infarct. When it occurs in the lungs, it is called a pulmonary infarct.<sup>9</sup>

*Tachycardia*—Abnormal rapidity of heart action.<sup>10</sup>

*Thrombosis*—The formation of a blood clot (thrombus). When a thrombus is detached from its original site, and is found in another part, it is called a thrombotic embolus.<sup>11</sup>

### **Anatomy and Physiology of the Heart<sup>12</sup>**

As an aid in understanding the anatomy of the heart and its function, see the diagram below.

The heart is a hollow, muscular organ which is the center of the circulatory system. It is enclosed within the pericardium (protective sac) and consists of a muscular substance (myocardium) which is lined with the endocardium. The heart is divided perpendicularly from top to bottom by a septum (membrane) into two parts, each having no connection with each other, the left side carrying arterial and the right side carrying the venous blood. Each side is further divided into two separate cavities connected by an orifice and guarded by a valve. Each lower cavity is the ventricle and each upper cavity is the auricle. Ventricles are pumping chambers, while the auricles are receiving chambers.

The heart's action is activated by the sinoauricular node (pacemaker), which generates a minute electric current. This current travels over the walls of the auricles, which contract, and then sets off contraction of the ventricles by exciting the auriculoventricular nodes and bundles in the ventricles. Contraction of the heart is called systole, while dilation of the heart is called diastole.

The right auricle receives waste-laden blood from the body through the inferior vena cava, and from the head through the superior vena cava. During diastole, the blood flows into the

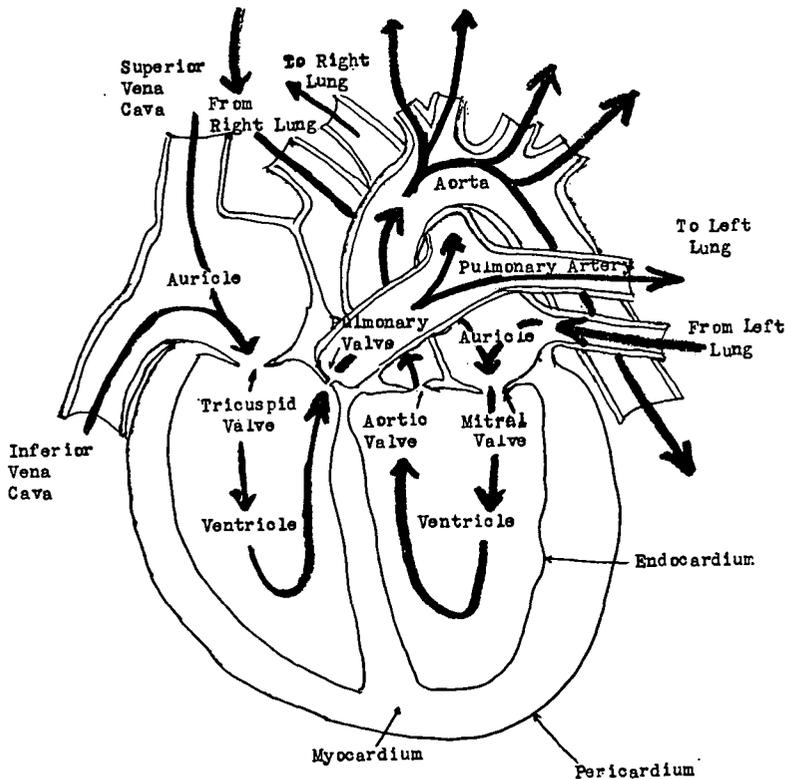
<sup>9</sup> *Supra*, note 1, at 745.

<sup>10</sup> *Supra*, note 2 at T-3.

<sup>11</sup> *Id.*, at T-31.

<sup>12</sup> White and Smith, *Scientific Proof in Respect to Injuries of the Heart*, 24 N. C. L. R. 107 (1946).

right ventricle through the tricuspid valve and is pumped during systole through the pulmonary arteries to the lungs for release of its acquired carbon dioxide wastes and oxygenation. The oxygenated blood is returned to the left auricle by the pulmonary veins through the mitral valve, during diastole, to the left ventricle, which, during systole, pumps the oxygenated blood through the aortic valve to all parts of the body. Due to its greater pumping action, the left ventricle is usually larger than the right.



The human heart beats an average of 72 times per minute, and it has been estimated that two to three ounces of blood are driven into the arteries by each heart beat. It is said that the power exerted by the heart is equal to that necessary to lift 80 pounds one foot each minute. In terms of work, this is the equivalent of raising one ton to a height of 82 feet every 24 hours.

## Types of Heart Disorders

There are many types of heart disorders, based on the factors which cause the malfunction. Necessarily, certain of these are more prevalent than others, and in outlining the various types of disorders and diseases, a classification into Major Types and Other Types has been made.

### Major Types of Heart Disease

#### *Rheumatic Heart Disease*<sup>13</sup>

Rheumatic heart disease is believed to be caused by a hemolytic streptococcal infection, although the precise manner in which such infections act to become rheumatic fever is unknown. "Strep throat" and scarlet fever are primary infections which most often develop into rheumatic fever. The disease occurs more frequently in under-privileged classes than the well-to-do, and affects children to a far greater extent than adults.

Rheumatic heart disease is generally classified as active or inactive. In active cases, there is inflammation present in either the pericardium (pericarditis), the myocardium (myocarditis) or endocardium (endocarditis). The symptoms may be dyspnea, pain in the chest and upper abdomen, fever, etc. Sometimes the carditis is insidious and the only symptoms are loss of appetite, fatigue and aching joints.

Inactive rheumatic heart disease refers to the stage of the disease in which the scarring, as the result of the carditis in the active stage, causes valvular deformities, weakness and dilation in the myocardium and pericardial adhesions. Sometimes patients with inactive rheumatic fever manifest no symptoms, while others experience arrhythmia and anginal pain.

Once rheumatic fever has been contracted, there is a tendency to recurrent attacks, with additional damage to the heart. Continuous prophylaxis, over a long period of time, by use of antibiotics (mainly benzathine penicillin) has proved effective.

#### *Hypertensive Heart Disease*<sup>14</sup>

Hypertensive heart disease refers to abnormalities of the heart as the result of high blood pressure over a long period of time. The causes of high blood pressure are unknown, but there

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<sup>13</sup> 2 *Cyclopedia of Medicine, Surgery, Specialties*, 985 (1961).

<sup>14</sup> Wood, *Disease of the Heart and Circulation*, 761-798 (2d ed., 1957).

appears to be an important correlation with heredity. Experiments have induced hypertension by constriction of the renal arteries (main arteries to the kidneys). These results could be explained by a slowdown of the kidney function, with resulting edema, which would constrict the blood vessels.

Other causes of hypertension which have been suggested are prolonged emotional strain, acute nephritis (inflammation of the kidney) and toxemia of pregnancy.

At any rate, the peripheral resistance to blood flow is increased by a reduction in the size of the blood vessels, and this increase of peripheral resistance causes the heart to work harder, and as a result, over a long period of time, the heart (mainly the left ventricle which has to pump against this increased resistance) tends to dilate. If the strain becomes excessive, the heart may fail altogether.

Hypertensive heart disease generally occurs between the ages of 40 and 70, with peak incidence between 50 and 59 years of age. Once the heart becomes enlarged as the result of hypertension, the outlook is not good, although some cases have shown improvement by bed rest and living at a slower pace. Other treatments include a low sodium diet, chemically blocking response to sympathetic nerve stimulation, and surgical resection of certain sympathetic nerves.

#### *Coronary (Ischemic) Heart Disease*<sup>15</sup>

Coronary heart disease is the most common type of heart disease, and is increasing. It is generally considered the result of atherosclerosis. The cause of atherosclerosis, while intensively researched, has not been absolutely determined. Current belief is that atherosclerosis is linked to fat metabolism disturbance over a long period of time. Other factors believed to cause the disease are physical activity, or lack thereof; degree of mental strain or stress; cigarette smoking; and standards of nutrition.

Coronary heart disease is overwhelmingly confined to the male under the age of 40. Between 40 and 50, the ratio is 8 to 1 in favor of the male. As age increases, the ratio of women to men increases until it is equal.

Under this classification also is included heart disease as a result of arteriosclerosis. At one time atherosclerosis and arteriosclerosis were thought to be due only to the aging process. While

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<sup>15</sup> *Id.*, at 701-752.

certain changes in the cardiovascular system are evident with the passing of time, such aging has been discounted as a major factor in coronary heart disease.

Coronary heart disease manifests itself in three ways: angina pectoris, acute coronary insufficiency, and cardiac infarction.

Angina pectoris usually occurs when the patient exerts himself, and is the result of the narrowing of the coronary vessels by atherosclerosis. The attacks are intermittent, with the pain short-lived during times when the metabolic demands of the heart exceed the coronary capacity. Treatment of angina pectoris includes correction of obesity, reduction in smoking (which habit reduces the size of blood vessels), relief of anxiety, and drug treatment (trinitrin, amyl nitrite, etc.).

Cardiac infarction occurs when a portion of the heart muscle is deprived of its blood supply for a length of time sufficient for that portion of the heart to die (usually caused by coronary thrombosis). It is possible, however, to have a coronary thrombosis and not suffer a cardiac infarction, where the collateral blood supply is sufficient to supply the needs of the area affected. In such a case, the result is acute coronary insufficiency.

Cardiac infarction patients are confined to bed for three to six weeks and, for the first few days, placed on an extremely low calorie diet. Morphine is used to relieve pain and induce rest, and anticoagulants (dicoumarol, heparin, etc.) are administered to prevent the extension of the coronary thrombosis.

Acute coronary insufficiency is the classification between angina pectoris and cardiac infarction, so far as severity is concerned. It covers the situation where there is a coronary thrombosis, but where no necrosis (death of tissue) occurs, because of the sufficient collateral circulation. Treatment includes bed rest and anticoagulant therapy to prevent an actual cardiac infarction.

### **Less Common Forms of Heart Disease**

#### ***Congenital Heart Disease***<sup>16</sup>

Congenital heart disease is usually caused by maternal illness during the first three months of pregnancy. It is not considered an hereditary defect, although certain types of congenital defects have been found to be familial. Congenital heart disease ac-

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<sup>16</sup> Id., at 318-461.

counts for approximately 2% of all organic heart disorders, and certain of them are capable of being corrected surgically.

### *Syphilitic Heart Disease*<sup>17</sup>

Syphilitic heart disease manifests itself as an inflammation of the aorta (aortitis). It generally does not appear until 10 years after the primary infection. Aortitis causes aortic dilation, necrosis and formation of aortic aneurysms (arterial sacs of blood due to pressure of blood on weakened tissues of the aorta<sup>18</sup>). Treatment consists of bed rest and therapy with standard anti-syphilitic drugs.

### *Non-Rheumatic Heart Disease*<sup>19</sup>

Cases of heart disease in this category are extremely rare. Causes under this classification may be divided into various groups, among which are: bacterial infections (diphtheria, pneumonia, tuberculosis, etc.); fungus infections; parasitic infections (trichinosis); virus infections (colds, influenza, poliomyelitis, etc.); nutritional disorders; endocrine disorders (thyrotoxicosis) and tumors.

### *Pulmonary Heart Disease (Cor Pulmonale)*<sup>20</sup>

In pulmonary heart disease, a condition, such as asthma or silicosis, or a disease, such as bronchitis or bronchopneumonia, develops in the lungs and blocks or partially blocks the blood vessels in the lungs. This increases the resistance to the pumping of the right ventricle, and thereby causes dilation of the ventricle, leading to possible failure.

Closely related to pulmonary heart disease is a pulmonary embolism, which arises when a thrombus breaks loose from the point where it was formed, moves through the veins to the right auricle and becomes lodged in one of the pulmonary arteries. It might also arise where the thrombus moves from inside the heart and lodges in an artery, thereby cutting off the blood flow to that area. Thrombi can be formed by local venous injury, as in thrombophlebitis, the injection of chemical irritants, by fractures or by cancers. They also result from the slowing of

<sup>17</sup> Id., at 683-699.

<sup>18</sup> *Supra*, note 2, at A-62.

<sup>19</sup> *Supra*, note 14, at 605-655.

<sup>20</sup> Id., at 806-868.

venous blood flow, as in obesity, immobilization or pregnancy, and by post-operative or post-traumatic states.

### *Heart Disease as the Result of Trauma*<sup>21</sup>

Major traumatic injuries to the heart are classified as direct and indirect. Direct injuries are those caused by penetrating wounds as the result of gunshot, stabbing or other perforations of the chest cavity. Such wounds may perforate the heart completely, or cause foreign matter to be lodged in the myocardium or pericardium. In cases of near misses, grazes or tangential wounds, the pericardium is also affected. The result of such direct injuries is hemopericardium (effusion of blood into the pericardial sac) and rapid development of cardiac tamponade (constriction of the heart by fluid in the pericardium). If the patient survives these complications, a further complication of pericarditis occurs, and is apt to be recurrent, if the foreign matter remains in the heart or in close proximity thereto. Pericarditis manifests itself in pain, fever, tachycardia and possible further cardiac tamponade. Treatment of direct injuries to the heart must be accomplished quickly and consists of paracentesis (puncture of a cavity with evacuation of fluid) and removal of foreign objects.

Indirect injuries to the heart are caused by heavy blows to the region over the heart, without penetration. Such injuries do not necessarily have to be major traumas, as it has been found in some cases that sudden immersion in icy water, extreme fright, or a blow over the heart insufficient to cause material damage may act so as to cause ventricular fibrillation (quivering) or cardiac standstill. There is some question as to whether such minor injuries are the cause of cardiac malfunction, or merely the trigger of an existing disorder.

Indirect injuries as the result of heavy blows may result in ventricular fibrillation or standstill, rupture of the aorta, ruptures of the chambers of the heart, ruptures of the valves or myocardial bruising. Coronary occlusion and subsequent angina pectoris or cardiac infarction may also occur, but these should be considered in the light of the proximity of their occurrence to the injury.<sup>22</sup>

<sup>21</sup> *Id.*, at 922-934.

<sup>22</sup> *Supra*, note 12, at 171.