

**PATHOLOGY**  
FOR  
STUDENTS AND PRACTITIONER'S

An exhaustive bibliography is included in the third volume, (pages 2225 to 2452), with references to the literature of Germany, France, Spain, Italy, Sweden, Switzerland, Denmark, Portugal, Russia, England and the United States.

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For greater convenience a complete index is included in each volume and the volume number is printed in italics. The references to illustrations are in bold face type.

While there is in the text a complete system of cross references to related subjects the index summarizes them for ready reference. Example, under the heading "Abscesses" there are 76 entries.

# PATHOLOGY

FOR STUDENTS  
AND PRACTITIONER'S

Authorized Translation of the  
Lehrbuch der Pathologischen Anatomie

BY

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IN THREE VOLUMES 1072 ILLUSTRATIONS

VOLUME I

PHILADELPHIA  
P. BLAKISTON'S SON & CO.  
1012 WALNUT STREET

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PRINTED IN U. S. A.  
BY THE MAPLE PRESS COMPANY, YORK, PA.

## TRANSLATOR'S PREFACE

Kaufmann's Lehrbuch has seldom been far from the reach of the translator from the time he first began his work as a professional pathologist, and sections of it had already been translated for general use in this laboratory before the seventh and eighth editions appeared, therefore it was only natural that he should undertake the translation of the entire work into English. The task has been considerable, but the reward has been commensurate, not alone in clarifying and systematizing the knowledge gained in the translator's active pathological practice, but also in the pleasure of entering closely with the author into discussions of his favorite subject.

As a result of twelve years teaching experience; of intimate contact with many young and active hospital interns, also of close association with clinicians and patients who have presented their problems for solution, the translator has acquired a firm idea of how pathology should be taught to students of medicine so as to make them fit, when physicians, to take proper care of the sick. He believes that the most important thing a teacher of pathology can do is to help prepare students to become good doctors. Hence in the few paragraphs which the translator has felt called upon to add to the work, he has endeavored to emphasize the relationship of pathology to the sick and how the knowledge of that relationship can help the physician.

The translator has the fullest sympathy with the viewpoint that has been stressed so much in recent years, namely, that of pathological physiology, consequently the reader will find much upon this subject in the text. It is well to remember, however, before we can say, or even speculate on how a condition occurs, and what its dynamics are, that it is necessary to know what it is, and this we shall learn from Kaufmann's pathological anatomy. Of what avail is a discussion of the pathological physiology of atrophic cirrhosis of the liver, when, in reality, the liver about which we are speaking shows, not atrophic cirrhosis, but biliary cirrhosis, due to ascending cholangitis which is secondary to cholelithiasis?

Pathological anatomy is an art as well as a science, in fact, about 80% art and 20% science. It takes time and experience to acquire the necessary familiarity and knowledge to assign or designate lesions properly. This, the time devoted to pathological anatomy pure and simple, cannot, in fact, dare not, be slighted if pathological physiology and subsequent clinical medicine are to be mastered.

Then, there is the problem of tumor diagnosis: If it is important to have clinical insight into other pathological subjects, it is doubly important in this. It is not to confuse the medical student in his undergraduate studies, nor to deny the broad general principles of tumor diagnosis which have been taught to him, but merely to implant a fact which should be implanted early, namely, that a correct diagnosis of many tumors cannot be made unless complete clinical data are submitted and considered in connection with the gross and microscopic pictures. And even then, we cannot always determine what the tumor is, but have to wait until time has elapsed and we have observed the sequelae in the patient. In other words, histological malignancy is not always biological malignancy, although, usually, it is; a section alone is not always sufficient to tell the whole story.

Naturally, many of those pathological conditions with which the translator has become especially familiar, such as diseases of the abdominal and thoracic viscera, could have been discussed in greater detail in the translation and his own point of view, or the point of view developed by the staff of The Lankenau Hospital as a group, could have been more emphasized. In most instances, however, it will be found that the author has at least mentioned them, so that, while the translator probably could have enlarged upon certain features, or thoughts, he feels that enough (little though it be) has been given to arouse the interest of the diligent reader.

The literature given by Kaufmann will be found in full, as in the German text. Some few references added by the translator will be found appropriately placed in the text itself.

Some liberties have been taken with subheadings and divisions, but in the main the original has been faithfully followed.

The drawings (considerably over one hundred) for the additional or supplementary pictures, which the translator thought would be materially helpful to the reader, were made by our staff artist, Mrs. W. B. Keighton (Eleanor M. Paxson) to whom he is deeply indebted for them. They are some of many which have accumulated in this laboratory during the last few years. These pictures are indicated by L. H. at the end of the legends.

The translator also has had much help, particularly from his assistant, Dr. C. E. Becker, and from Miss L. Snellbaker. He wishes also to record his thanks to Miss M. T. Shutt for her faithful writing of the manuscript, much from dictation, more by way of mechanical devices.

He also expresses thanks to the publishers for their patience and care throughout the preparation of this edition.

## PREFACE TO THE SEVENTH AND EIGHTH GERMAN EDITION

The sixth edition of this book was so well received at home and abroad in spite of its unusual size, that two reprints were necessary. In his endeavor to improve the subject matter of this combined edition, the author has increased the length and scope of each chapter so as to present as nearly as he could, a complete picture of our present objective knowledge. Thus the text has been enriched in many directions, particularly from experiences acquired during the World War.

An esteemed friend, a specialist in this line, was kind enough to say that the author had produced not merely a good text book with the didactic advantage of uniform conception and presentation, but a book suitable for reference by any one who required for whatever reason, a concise text book of special pathological anatomy; others were good enough to concur in this opinion. Students of medicine are always foremost in the author's mind, and thus the subjects which he regards as the most important for those who are to be our physicians, have been handled with special insistence and with detail; to complete the viewpoint, make it clearer to the understanding and at the same time to maintain interest, excursions are made into embryology, anatomy, physiology and general pathology.

Faithful to the thought that was expressed in the first edition of this work, the close connection between pathological anatomy and practical medicine, or between theory and practice, is emphasized by numerous references to clinical data. Readers who desire more details in any subject or who wish to trace all the sources, will, I hope, find the road well mapped out by the details in the text and by the references to the literature.

The number of illustrations is increased by several hundred, most of them from sketches made by the author of specimens in the Pathological Institute of Basle and in the collection at Gottingen. A number were also obtained from plates published in Virchow's Archives. Volume 3 contains the index and references to the literature which have been increased by many thousands. Although the latter occupies considerable space, this wealth of literature is indispensable in the opinion of his colleagues, Prof. Pio Foa and Prof. Sapegno, editors of the Italian translation of the book; the author, therefore, has not shirked the labor of its further extension; to ensure the utmost reliability he has included only such works as he himself has checked.

The author expresses his thanks to many colleagues in pathology and to numerous clinicians and specialists in other lines both at home and abroad for their kindness in sending him monographs and reprints; he hopes that this help will be forthcoming in the future also.

To Drs. Staemmler and Husten, the author also tenders his thanks for their valuable help in the preparation of the book.

EDWARD KAUFMANN.

GOTTINGEN

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# PATHOLOGY

## CHAPTER I

### ORGANS OF CIRCULATION

#### HEART

##### PERICARDIUM

The pericardium is a serous membrane resembling a completely closed sac into which the heart has been pushed. Its wall consists of connective tissue rich in elastic fibres lined by an elastic basement membrane on which rests a single layer of low cells called endothelium or epithelium which become cubical to cylindrical during irritative processes and during regeneration, (see p. 8). The pericardio-pleuro-peritoneal cavity is formed from splitting in the mesoderm; its covering cells are modified mesenchyme or connective tissue cells, originally epithelial-like, almost cuboidal, but changing to flat serous endothelial cells. After death they quickly become detached; cilia have been demonstrated in these cells, (see Paladino, Kolosow, Muscatello, v. Brunn, lit.). The pericardium consists of two layers:

(a) The visceral layer or epicardium covers the heart and the proximal part of the large vessels—aorta and pulmonary arteries—to which structures it is firmly attached.

(b) The parietal pericardium surrounds the epicardium and the heart; it is quite distensible and elastic.

Malformations. Defects of the diverticuli and parietal layer, especially the left, are extremely rare; (Rohn, lit., Verse, Perna, Ebstein, Plaut, lit., Cameron, Lang).

A defect of the pericardium may accompany a sternal fissure, *i.e.*, a space in the sternum closed by fibrous tissue through which heart movements can be felt and seen during life. In *ectopia cordis pectoralis* (see malformations of the heart), the perfectly developed heart has no pericardium (*Ect. nuda cordis*) or may be surrounded by it.

##### Changes in Its Contents

The pericardium contains normally 5 cc. to 20 cc. of a clear yellow serous fluid, and more after a long agonal period.

If the fluid is absent at autopsy it is a post mortem phenomenon, because of evaporation towards the lungs, and the parietal layer may appear dry and like parchment on those areas where it is attached to a lung containing much air (emphysematous).

The pericardium has an almost reflecting sheen on account of its homogeneous cellular surface, its tendinous smooth structure, and the moistening with the serous fluid of the cavity. An increase of this normal fluid up to 150 cc. and more (1 litre and more) is called:

#### HYDROPERICARDIUM. HYDROPS PERICARDII

The fluid is amber colored or greenish, clear, contains albumen, is alkaline and called a transudate (non-inflammatory). But it frequently contains traces of fibrin which, on exposure to air, separate out as a cloudy gelatinous substance. Considerable amounts of fibrin are always a sign of an inflammatory exudate. Isolated round and endothelial cells, swollen and undergoing fatty degeneration, are almost always found in this hydropic fluid. The pericardial angles are rounded with the accumulation of the hydrops.

In the cadaver, the fluid often is stained red by absorption of blood coloring matters. When effusion of blood takes place during life and is followed by hemolysis, the fluid is stained a dirty brown or wine red color. In icterus, it is golden or bile yellow. With the cadaver in the dorsal position, the heart floats approximately in its normal position on the surface of the liquid (Schaposchnikoff, see against it, Damsch, and for it, Romberg).

**Etiology.**—Hydrops pericardii may be a concomitant of general anasarca whether from circulatory changes, stasis, or functional disturbances of the heart itself—cardiac hydrops—which may be chronic—heart lesions—or may only be agonal; or may be due to increased permeability of the vessel walls, blood changes—hydremia—or to cachexias from various causes, and especially chronic nephritis with disturbed renal function; hydrops may be idiopathic which is quite rare, and occasionally found in old people with cardiac atrophy (hydrops ex vacuo).

The transudate results from the passage of fluid blood constituents from the capillaries into the surrounding tissues, in this case to the surface of the serosa; according to Ludwig's theory, filtration, because of increased pressure within the vessels is the physical reason—or according to Cohnstein's theory, diffusion, a movement of fluid outward from the capillaries caused by osmotic pressure differences in which permeability operates in a way similar to that of a colloid; under pathological conditions, the fluid varies and thus there is a corresponding change in permeability

(Klemensiewicz). The physiological transudate is the lymph or blood lymph. Heidenhein's theory assumes it is formed by secretion of the endothelium of the capillaries. Hamburger applied this theory to the formation of hydrops. Thus in "mechanical hydrops" due to stasis, the secretory activity of the endothelium is influenced by blood stasis in such a way that the accumulation of metabolic products stimulates the endothelium to increased lymph secretion. Hydrops resulting from increased permeability of vessel walls is to be explained by assuming that the vessel wall loses the secretory function of the endothelium and becomes permeable like a filter, while in other cases it results from pathological stimulation of the capillary endothelium by lymph stimulants from pathological processes, especially of infectious origin; the action might be conceived as analogous to those demonstrated after administration of hirudin, decoction of crab muscle, peptone, and certain bacterial cultures. According to Asher's cellular physiological theory, secretion from tissue cells and the endothelium of lymph vessels and serous cavities is made responsible for the formation of lymph, *i.e.*, cavity hydrops, but without exclusion of transudation from blood vessels.

Absorption of a larger transudate is by reabsorption into blood vessels by diffusion. Absorption by lymph vessels must occur very slowly if at all under these conditions (Klemensiewicz).

**Consequences.**—In marked hydrops, there is demonstrable thinning of the parietal pericardium with disappearance of the epicardial fat, while the heart itself becomes smaller. Even in large accumulations in the pericardium, the work of the heart is remarkably little impeded, but the left lung may be displaced and compressed and thus interfere with cardiac activity.

**Translator's Remarks.**—The *pulsus paradoxus* occurs during respiration, *i.e.*, a waxing and waning rhythmic pulse. The flow of blood into the heart is impeded by the increased intrapericardial pressure; pressure on the veins outside of the heart is increased and decreased during breathing; the difference thus varies in the pressures in the heart and in the veins, it being less during inspiration so that less blood can enter the heart. See *Katz L. N. & Gauchat H. W.*; *Arch. Int. Med.*, 1924, 33, 371.

#### HEMOPERICARDIUM

The pericardium may contain blood. The membrane may be (*a*) intact, if, for instance, the heart ruptures and there is pure hemorrhage— or (*b*) there may be a disease accompanied by exudation, either simple or specific, usually tuberculous or carcinomatous, and the hemorrhage results

from newly formed vessels (compare hemorrhagic inflammation) and there is a mixture of blood and exudate. But there may also be a special tendency to hemorrhage on the basis of a dyscrasia, such as in scurvy, tuberculosis, carcinoma, etc.

If the pericardium contains large quantities, 200 cc. to 300 cc., rarely 500, even 800 cc., or up to several litres, after opening the thorax, it appears bulging, rounded, dark blue violet, or gray black, translucent, and displaces the lower parts of the lungs. Such conditions are seen: 1. under circumstances mentioned above (*b*); thus, occasionally, in tuberculous pericarditis, large quantities of almost pure blood are found. As a rule, striking functional disturbances of the heart are absent in these chronically developed blood mixed exudates. 2. An acute, pure hemorrhage into a healthy pericardium may occur in (*a*) spontaneous rupture of the heart wall, from chronic cardiac aneurysm, necrosis after occlusion of the coronary artery; high degree of fat infiltration, especially if combined with brown atrophy, usually in the left heart of old people; rarely with abscess, observed even in a suckling (Schaps); in acute parietal aneurysm (Hart), and finally in neoplasms and animal parasites (lit. by Romeick); (*b*) from rupture of aneurysms especially of the dissecting type, of the part of the aorta situated in the pericardium [for lit. and discussion of case in boy sixteen years old see Richey, De W. G., Arch. Int. Med., 1923, 31, 232.—*Translator*]; quite rarely from aneurysms of the coronary artery, (lit. Auffermann, Sommer), or of the pulmonary artery, or from rupture of an atheromatous coronary artery, and very rarely from a coronary vein (Pepere); (*c*) from trauma such as bullet and stab wounds of the pericardium and also the epicardium, (thus the author saw death after injury to a vein), but especially of the heart itself; from other forms of trauma, traumatic cardiac rupture with direct injury, bone fracture or compression; or in true rupture, either from internal pressure or tearing (Revenstorf, Bernstein, lit., Neue, Jaffe). The blood coagulates quickly or remains fluid, and 250 cc.—300 cc. suffice as a rule to cause death from tamponade of the pericardium, with the tension it causes whether by heart compression (Rehn) and the consequent prevention of diastolic expansion, or, analogous to the oil tension experiments of Cohnheim, from prevention of the emptying of the cavae in the auricles. As an exception, with a very powerful heart muscle, one litre may be found. The time of death depends on the kind of opening through which the blood escapes. In a large spontaneous rupture, death is sudden from paralysis of the heart, also in rupture from compression. In other cases of spontaneous rupture, death results later, perhaps after hours and even after days, if the tear is completed only after later enlargement (Ebbinghaus).

**Translator's Remarks.**—Thus in a 62 year-old woman, death occurred thirty-six hours after an initial and very severe pain. A cardiac aneurysm ruptured, and at autopsy 500 cc. of blood were found in the pericardial sac.

In stab wounds, and even more so in those prognostically unfavorable bullet wounds, this is often the case. The injured person can carry out complicated actions, defend himself, etc., a fact of great medico-legal importance (Ehrenroth). There is often time for satisfactory surgical treatment (Goebell, Borchardt, lit., Beck, lit., Luxemburg, Hesse, B. Fischer, Geringer, Hofmann, H. W. Gierke, Meyer-Pantin). Cases of perforating bullet wounds of the heart with heart tamponade without perforation of the parietal layer of the pericardium are described by De Josselin de Jonge, lit.

Traumata may be followed by inflammatory changes—pericarditis—especially if the pointed instruments such as needles, etc. are unclean. The author saw a case of suicidal intent in which a needle had been forced through the sternum, causing hemorrhage into the pericardium, accompanied by fibrinous pericarditis. Death resulted in a few days. The right ventricle during its movements, scratched its surface on the almost immovable needle, and thus arose the hemorrhage.

Small hemorrhages—ecchymoses—into the pericardial and subepicardial tissue especially on the posterior wall towards the base are seen frequently in asphyxia, especially in the newborn in whom the posterior coronary sulcus is chiefly the place affected, but there are usually hemorrhages into the pleura, thymus, etc., with severe agonal dyspnea. They are also found in poisoning (phosphorus), in septic infections (osteomyelitis), in hemorrhagic diatheses, in blood diseases, leukemia, pernicious anemia, and in eclampsia. They may appear as slate colored to black pigment spots, rarely nodules, and very rarely diffuse black discolorations of the parietal pericardial surface, (Borst). (Compare also subendocardial hemorrhages, p. 21.)

By applying, experimentally, relatively slight force to the thorax, Kulbs induced traumatic ecchymoses and hemorrhages into the valves and muscle.

Anthraxis may also be responsible for brown or black spots in the pericardium, brought there through the lymph channels from anthracotic bronchial and mediastinal lymph nodes. An actual evacuation into the cavity and rubbing into the epicardium must be very rare (Askanazy).

#### PNEUMOPERICARDIUM

Air or gases are found very rarely in the pericardial cavity. They may enter through an osophageal rupture (trauma, foreign body, cancer), or

from the stomach, (cancer or simple ulcer), more rarely from the lungs or the pleura, (cavities, pneumothorax). Wounds from without penetrating the pericardium can allow entrance. Decomposition of exudates may produce gases. The term pneumotosis pericardii should be used only if the interstices of the pericardial tissue are filled with gas bubbles.

### Inflammation of the Pericardium. Pericarditis

The different anatomical forms are determined by the kind of exudate; thus there are differentiated:

#### SEROUS AND FIBRINOUS, OR SERO-FIBRINOUS PERICARDITIS

A pure serous pericarditis, the exudate of which differs from the transudate of hydrops by its greater content of albumen, higher specific gravity and greater coagulability, does not remain for any length of time, but changes quickly to a sero-fibrinous pericarditis. After a preceding inflammatory hyperemia, dilatation and increased permeability of the pericardial vessels, the surface is coated with an albuminous fluid containing lymphocytes and isolated leukocytes and from which fibrin is deposited in granular form or as minute fibrils



FIG. 1.

FIG. 1.—Pericarditis, fibrinous acute; m, heart muscle fibers; p, pericardial connective tissue with blood vessels and elastic fibers in which is cellular infiltration, especially marked at the boundary; g, above f, fibrin deposit; above g, lining cells are absent.



FIG. 2.

FIG. 2.—Fibrinous productive pericarditis; granulation tissue G, rich in vessels and young cells penetrates the fibrin f, which has been deposited on the surface in new layers; med. magn.

often interlacing, or as a substance of fine fibres, or as a homogeneous deposit. In the beginning the process is usually circumscribed.

The serous layer loses its mirror-like gloss, a sure sign of serous inflammation. The pericardium suggests a pane of ground glass; after rubbing the back of a knife over the epicardium, it is dry, suffers an alteration of its

surface, the cellular coating is soon lost and it is covered with a veil of fibrin.

The covering cells are exfoliated after swelling and granular or fatty degeneration, or they lose their nuclei and undergo necrosis. There are gaps, and between the cells are fine fibres or broader strands of fibrin extending upward and loosening the cells. Finally the fibrin is directly attached to the connective and elastic tissues below. In early cases, there are still well preserved endothelial cells here and there on top of the fibrin, indeed to a small degree there are evidences of reproduction and regeneration. In other areas, the cells are covered by the fibrin membrane. In the pericardial vessels also, from which, naturally, the exudate has come, there may be a fibrin network or collections of leukocytes. Sometimes there is fibrinous exudate in the upper layers of the serosa itself.

The exudate, somewhat turbid from the admixture of leukocytes and desquamated surface cells, is usually yellow in color or red from slight hemorrhages and may contain free fibrin flakes. Its quantity varies and may reach one litre. In other cases it is so small that the term pericarditis fibrinosa sicca is used.

The fibrin often precedes the appearance of the serous exudation. If the serum is reabsorbed, the fibrin may remain. Thus are explained the remarkable changes in the clinical symptoms, friction, its disappearance and its recurrence.

If the coating of fibrin is thin, the markedly filled red pericardial vessels can be seen shining through in the vicinity of hemorrhages. In its fresh state, the membrane may be rubbed off by a knife and the mirror-like smooth serosa reappears. If the layers are plastered close on top of each other, especially the case on the visceral layer, the landmarks of the heart are more or less effaced. If the heart is covered by fibrin masses of light grayish yellow, or grayish red especially in the deeper layers from admixture of blood, and if it is like a network, or is furry, like a coat of sheep skin, it is called *cor villosum* or bread-and-butter heart. The fibrin masses first feel tough and somewhat rough but later become soft and friable.

The deeper layers of the pericardium in contact with the muscle are always hyperemic and show small round cell infiltration; the endothelial cells of blood and lymph vessels are enlarged.

Sometimes the fibrin masses are arranged as fringed masses over the left ventricle, especially at the apex, while on the edge of the right ventricle they appear as though combed. These latter are often approximately in parallel bands arranged at right angles to the long axis of the ventricle. On the part of the ventricle nearest the auricle, and above the *conus pulmonalis*, *i.e.*, on those parts which move the least during heart

action, the fibrin is deposited as a thick network or in honey comb layers. In the cases of dry fibrinous inflammation, the surfaces adhere and become displaced, so that the formation of typical figures can hardly take place. These develop best when there is much fluid and adherence of the pericardial walls is impossible, at least, over the more movable parts of the heart. The explanation of this peculiar arrangement lies in the continuous, regular and extensive movements of the heart muscle, especially during its contraction. In this way the fibrin masses deposited on the heart are pushed together in ridges as we see them on the right ventricle, while in other places, the fibrinous adhesions on the parietal pericardium are constantly torn apart again and fringes are formed especially at the apex. On the parietal layer these figures do not form typically.

#### FURTHER COURSE OF FIBRINOUS PERICARDITIS

(a) **Absorption.** *Healing.*—The pericarditis may remain as described and then regress. The stiff exudate softens and breaks down into a granular detritus rich in fat droplets, and thus can be absorbed, but is also partly taken up by leukocytes and carried off (fat granule cells). Hyperemia disappears, the surface cells regenerate from those left behind and everything returns to normal. The softer the exudate, the quicker the pericarditis disappears, sometimes even in 24 hours, but usually the process takes place as in (b).

(b) **Organization of the Exudate by Productive Pericarditis** (*Fibrinous Productive Pericarditis*).—If the inflammation does not subside quickly, it assumes a productive character. Doubtless, the fibrin exerts a chemotactic effect on the connective tissue cells and blood vessels of the pericardium beneath. This leads to the production of a vascular granulation tissue from the connective tissue parts of the pericardial vessels which lifts the fibrin upwards. Or, more usually, the young tissue, rich in ameboid cells and budding vessels, penetrates the elastic border membrane and grows into the gaps between the fibrin masses which are more and more surrounded and broken up; they are then absorbed and the mass of fibrin is reduced to small islands. All of these processes take place in the course of a few weeks. Later, this granulation tissue in which the polymorphonuclear leukocytes are more and more reduced in numbers, changes into connective tissue and finally to scar tissue, poor in cells and vessels. Thus the healing process is concluded.

The gaps in the fibrin, or the spaces between the old and the newly formed tissue, or within the latter, may be lined with enlarged cubical surface cells on which fibrin perhaps exerted a stimulating effect and thus duct-like structures are formed (comp. p. 13, lit.), and Lauche saw cysts suspended like drops from the heart and lined with surface cells.

The growth of the granulating pericardium into the fibrin soon makes it impossible to pull off the deeper layers of fibrin.

#### GENERALITIES ABOUT GRANULATION TISSUE AND ITS CHANGE INTO CONNECTIVE TISSUE

Granulation tissue consists (1) of thin walled blood capillaries formed in great numbers by budding from older vessels; and (2) of a germinal tissue consisting of ameboid cells of diverse shapes; the former arise first as thick cellular outgrowths or buds of endothelial cells which become canalized and carry blood, the endothelial cells being distinguished by marked staining properties and the size of their nuclei. The germinal tissue contains: (a) as essential elements, young connective tissue and granulation cells, also called formative cells or fibroblasts (E. Neumann, Ziegler). They are produced by growth from fixed connective tissue cells—karyokinetic figures—are larger than leukocytes and show rounded or epithelium-like angular (epithelioid) or club-like, or many branched, but particularly spindle shaped forms with large, vesicular, light staining nuclei often with several nucleoli. Rounded polygonal descendants of the proliferating connective tissue cells are often found as energetic phagocytes with large nuclei, especially as the so-called pus phagocytes in purulent membranes; their protoplasm is foamy and often contains doubly refracting cholesterol derivatives, when they are called pseudo-xanthoma cells. But such macrophages may also come from lymphocytes (see Krompecher). (b) Lymphocytes. Lymphocytes are the cells which lie isolated in every normal, vascular connective tissue and which, with their derivatives, the plasma cells, produce the so-called small cell infiltration encountered in chronic inflammations in interstitial tissue, especially in the neighborhood of vessels, particularly veins. Their sources are partly from blood and lymph vessels and their capacity to wander is proven (emi- and immigration, see under tonsils), (Naegeli, Almkvist, Proescher, Schridde). They are also said to be derived from the preformed small lymph nodules of the organs (Ribbert) or by heaping up and local multiplication of the indifferent wandering cell of the connective tissue which is distributed everywhere, or from adventitial cells. ("Small ameboid wandering cells," Maximow.) They are small, but slightly larger than erythrocytes, rounded, uninuclear, very poor in protoplasm so that the hardly perceptible cell body surrounds the small, round, intensively staining nucleus like a pale ring. From these lymphoid cells, according to the accepted opinion, are derived the plasma cells or plasmocytes (see Marchand, Porcile, Martinotti). They have basophilic protoplasm and vacuoles, and are differentiated into those with young nuclei (lymphoplastic), with normal nuclei. (lymphatic) and with "spokes of a wheel"

nuclei, the latter being larger oval cells with eccentrically placed nuclei; the peripheral chromatin of the nucleus stains dark blue with methylene blue and bluish green with methyl green (wheel nucleus) while the protoplasm surrounding, is light, finely grained or grumous, (Marschalko). They also wander in the tissues. According to Unna (lit.), plasma cells are formed from modified connective tissue cells of every kind and not only from adventitial cells. They can degenerate by vacuolation (foam cells) or hyalinization (hyalin or Russel's fuchsinophile bodies). (c) The third types of cells are large round cells with relatively small, lightly stained nuclei and finely granular or vacuolated protoplasm. They are pronounced phagocytes (macrophages of Metschnikoff) and may contain, among other things, smaller cells (lympho- or leukocytes). Marchand calls them large mononuclear wandering cells (macrophages), and classes them among the so-called leuko- or better, lymphocytic cells which, as a whole, have their source in indifferent cells of the adventitia of capillaries and small veins. These are Maximow's so-called resting wandering cells, or Ranvier's clasmatocytes which, according to Ranvier, are leukocytes which wander from the vessels and become perivascular and sessile, and which may change into delicate long cells with rounded or elongated nuclei and prolongations of cytoplasm. These may further differentiate into lymphocytes and plasma cells, into mononuclear leukocytes or into these macrophages or even into giant cells (see also Herzog). Maximow speaks of polyblasts which he believes develop only during inflammations from both wandering lymphocytes, and resting wandering cells. Marchand thinks they are similar to the common wandering cells so generally present in the connective tissues and of about the same significance as its lymphocytes. Goldmann considers the pyrrhol cells which store blue pigment in their granules after intravital pyrrholin injections, identical with connective tissue wandering cells. Mobilized reticulum cells and endothelial cells (histiocytes, see under blood and spleen), are also supposed to belong to the mononuclear macrophages, (see monocytes of blood, and comp. Aschoff-Kiyono). (d) The fourth group are the leucocytes, polymorphonuclear or with multiple nuclei; well staining cells which wander from the blood vessels and appear in varying numbers and groups of different sizes in close proximity to vessels. They are also found heaped up in the lumina of blood vessels in the youngest parts of the granulation tissue. The histiogenic mast cells must be differentiated from the blood basophiles; according to Staemmler, they are unicellular glandular organs of connective tissue which furnish the necessary mucin required for the formation of interfibrillary cement substances. They usually occur in small numbers while occasionally eosinophilic leucocytes appear in greater numbers. Giant cells are much less frequent; they contain many nuclei,

are merely large granulation cells or are derived from blood vessel endothelium or from leucocytic cells (see above, under *c*). As foreign body giant cells, they serve to remove material difficult of absorption. It is of diagnostic importance to differentiate them from the giant cells of Langhans, (see under tuberculosis).

During the change of granulation tissue into fibrillar connective tissue the polymorphonuclear leucocytes as well as the lymphocytes gradually disappear. But the large connective tissue cells increase in number; in their protoplasm, fibrillae differentiate, fringes of fibres, bands and bundles of fibrillae form, while the cell bodies become fainter, and it might be thought that between the cells was formed at first a homogeneous interstitial substance from which later wave-like fibrillae differentiate, but Marchand assumes that the fibrillae of the ground substance have the same origin as the bundles. In this way the transformation to cicatricial tissue progresses until the whole consists of a firm fibrous background in which shrunken cells repose within the tissue spaces. These small cells, often with long nuclei, remain as fixed connective tissue cells which hug the fibrillar bundles closely. The older the scar tissue, the more the fibrous bundles predominate, while cells and vessels are very sparse; scar tissue hardens and contracts from shortening of the fibres.

If this vascular granulation tissue grows into the fibrinous masses from both sides, the two surfaces of the pericardium become adherent by broad flat, (sometimes only by small) fibrinous bundles, and a connected organized mass consisting of vascular granulation tissue which replaces the disappearing fibrinous adhesions (adherent pericarditis). The free surfaces of the membranes become covered with surface cells.

Adhesions from fibrinous exudation is an essential preliminary to obliteration of the space or parts. This applies to all serous membranes.

If, after disappearance of the fibrinous exudate, the productive fibrinous pericarditis is ended and healing takes place, the granulation tissue becomes connective tissue which in time becomes poor in vessels and shrinks.

During this process, the organizing fringes may change to polypoid or fringed fibrous nodules, and the non-adherent parts of the surface may show fibrous thickenings; rarely there forms a thick coating (zuckerguss), (Eichhorst) which the author has seen covering various abdominal organs (liver, spleen, etc.). Surfaces which were adherent may unite through spotted laminated adhesions or fibrous bands and cords stretched by the motion of the heart.

According to the degree, there are partial, but sometimes total, fibrous synechiae of the pericardial surfaces. If the pericardial cavity is thereby obliterated, it is called obliterating pericarditis.

Pericardial adhesions occur much less frequently than those of the pleura.

Partial synechiae appear most frequently as relaxed, small threads or bands with broad bases inserted on the cardiac surface near its apex or close to the base. When there is complete obliteration, the growth usually consists of the connective tissue arranged in layers with sufficient looseness to allow of their displacement. Even if the adhesions are short and tense and the pericardium is callous and thickened—fibropericarditis—or if there is complete inseparable coalescence of surfaces—which of course is usually not the case in rheumatic and simple infectious forms of pericarditis but only in tuberculous types—the heart action, its motility and especially its contractility can still be comparatively free, particularly if a well developed subserous fat deposit underneath the epicardium supplies a comparatively movable layer. But if this movability is absent, even when the adhesions are localized (Achelis), the adhesions themselves become clinically noteworthy from a systolic pulling in at the region of the apex (comp. Erben).

**Consequences.**—There is often secondary involvement of the myocardium; both ventricles become hypertrophic especially the left, (Wideroe) or, contrariwise, the muscle atrophies or undergoes fatty degeneration; the cavities then enlarge, often only in the right heart, and severe circulatory disturbances manifest themselves. Rarely is the myocardium intact. In marked chronic exudation, the myocardium, especially its surface layers, shows fatty degeneration; if this causes decompensation, congestive symptoms develop leading to hydrops. The left lung may be compressed by a large pericardial exudate and thus be emptied of air.

**Cicatrical Mediastino-pericarditis.**—When a pericarditis extends through to the outer surface of the pericardium—pericarditis externa—the cellular mediastinal tissue may become involved in the exudative process and later cicatrization. This may interfere with the blood flow in the large vessels, clinically shown by pulsus paradoxus, (Kussmaul), and inspiratory swelling and diastolic collapse in the veins of the neck. Wenckebach calls attention to an inspiratory pulling in of the lower sternal angle and its vicinity, instead of the normal lifting movement.

Cicatrical change in a productive pericarditis on areas free from adhesions leads to the formation of diffuse icing-like, or circumscribed veil-like thickenings called tendon spots, macula tendinea sive lactea, or soldier's spots.

Under this term are considered two separate changes, not always easy to differentiate:

(a) Those, the result of a productive pericarditis, a localized pericardial fibrosis. These white thickenings readily testify to their inflamma-

tory origin, if the surface shows thread-like, fringy or small nodular connective tissue outgrowths, *i.e.*, if they are rough and uneven, but if they are smooth, they may be mistaken for simple pericardial scars. They often appear on both surfaces.

(b) Simple peri- and epicardial scars of non-inflammatory origin and consisting of sclerotic connective tissue poor in cells are very frequent and found in about 80% of cadavers, particularly, and regularly in old people. They may appear on both surfaces, but this is unusual. Generally they are located anteriorly on the right ventricle on the conus of the pulmonary artery, but may also be found on the posterior surface of the ventricles, in areas where the pericardium covers the large vessels, where the vena cava enters, and at the branchings of the coronary arteries. They are smooth, white, satiny thickenings of the pericardium often angular, sometimes rounded or oval, usually well circumscribed, either thin and transparent or thick, firm and tendonous, and often laid down like a



FIG. 3.—Pericardial milk spot with gland-like proliferation of cubical lining cells; low magn.

plateau; they may reach the size of a silver dollar or more. They sometimes appear as small nodules. Probably the form most frequently met is from mechanical causes (Friedreich), such as pulling, friction, and pressure, from heart action, and are then callous work hypertrophies with degeneration from hyalin and sclerotic changes without increase in elastic fibres as in scars. Herxheimer assumes they arise from primary mechanical lesions of the surface cells (comp. also Tsunoda). This explanation does not satisfy in some cases, *e.g.*, in small children; Czerny thinks they are the remains of adhesions with the amnion, (amnion spots); Ribbert supposes they result from disturbances in the separation of the leaves of the pericardium.

Microscopically, the connective tissue layers may include dainty gland or duct-like formations and spaces lined with cubical cells which originate from the surface cells, (comp. p. 8). (See R. Meyer, Ribbert, Tsunoda, Tsiwidis.)

Petrification results if lime salts are deposited in larger quantity which occurs relatively seldom. (The cheesy and fibrinous masses in tuberculo-

sis may calcify and the heart be surrounded more or less by flat or spiky lime deposits in a broad ring or armor—petrified heart.)

Clinical signs may be absent.

We have rarely seen extensive changes of this sort. True ossification of the pericardium is also rare.

(c) **Chronic Productive Pericarditis.**—Although every productive pericarditis following fibrinous exudation is chronic in a certain sense on account of the slow healing which extends over weeks, the inflammatory process nevertheless has a reparatory character since it absorbs and replaces the exudate. Productive inflammation becomes truly chronic—a chronic fibrinous productive pericarditis—when new fibrinous exudate is continuously deposited while the granulation tissue from beneath penetrates and replaces it and slowly and continuously changes to connective tissue. In this way, the pericardium becomes much thickened, up to 0.5 cm. and often over its entire surface.

If a new fibrino-exudative process occurs after the conclusion of one inflammatory process, it is called recurrent fibrinous pericarditis.

Anatomically this can be diagnosed quite accurately by finding new fibrin deposits on a scarred thickened pericardium with absence of cellular granulation tissue.

In rare cases, no adhesions occur, but there is marked shrinking of the whole heart.

#### PURULENT, SUPPURATIVE AND ICHOROUS PERICARDITIS

The first may occur alone or combined with sero-fibrinous pericarditis; in the latter case the fibrin masses are smeary, soft, and half dissolved. A true purulent exudate is creamy, thick, yellowish green, and consists of albuminous fluid plus enormous masses of pus cells, the polymorphonuclear leucocytes predominating.

Rarely, we see not only purulent exudation on the free surface, but also partial suppurative tissue destruction of the pericardium itself.

If healing by absorption or death does not occur soon, a productive inflammation quickly develops with the pericardium resembling a “pyogenic membrane,” containing pus phagocytes, (comp. p. 9). If this condition has persisted for some time, we find the pericardium remarkably large and thinned, or perhaps thickened by fibrous tissue; if many adhesions form, the pericardial cavity shrinks and finally is obliterated.

The exudate, even if plentiful (up to 1 litre), can undergo fatty degeneration and be reabsorbed, although slowly; occasionally it thickens like cheese and calcifies and then shows lumpy, chalky or plate-like, hard as bone, masses between the adhesions (do not mistake for tuberculosis).

Purulent pericarditis often invades the neighboring structures, especially the cellular tissue of the mediastinum, and sometimes the myocardium also. From purulent pericarditis may develop through decomposition, an ichorous fluid, greenish, foul and filled with gas bubbles.

**Results.**—Purulent, ichorous pericarditis is very grave. Death may ensue from paralysis of the heart which occurs, not rarely, from fatty degeneration of the myocardium; in other cases which end quickly in death, an inflammatory edema of the myocardium is the cause.

#### ETIOLOGY OF FIBRINOUS, PURULENT AND FIBRINO-PURULENT PERICARDITIS

Pericarditis in most cases is secondary, usually hematogenous in origin from some focus in another part of the body. It occurs most frequently in infectious diseases, particularly acute articular rheumatism which usually includes the endocardium also. Nenninger found cardiac complications in 60% of the cases of articular rheumatism, (see also under joints). But pericarditis does appear, although more rarely, in other infectious diseases such as scarlet fever, measles, small pox, cholera and even gonorrhoea. It is relatively frequent in chronic nephritis, chronic alcoholism, and other cachexias.

It is a question in nephritic pericarditis whether there is not a peculiar predisposition on the part of the pericardium to harbor microorganisms, or whether it is occasionally due to a purely toxemic (uremic) cause without bacterial activity (Banti). In uremic pericarditis, Marchand-Herzog found a remarkable proliferation and desquamation of the surface cells between the fibrinous membranes while leucocytes as well as lymphocytes were almost entirely absent (compare under endocarditis p. 37).

The suppurative variety is less frequent than the sero-fibrinous, and develops by metastasis especially from severe pyemic processes such as puerperal fever. The author has seen this form arise from circumscribed phlegmons in connection with felons, or furuncles or tonsillar abscesses; occasionally it is seen in articular rheumatism and in chronic nephritis.

In other cases it results from contiguity, (*b*) *i.e.*, from disease of the myocardium—abscess, tumor, chronic myocarditis—from the endocardium, or from neighboring structures.

This means from inflammations of the pleura or lungs, inflammatory processes, mostly purulent or ichoric, of the esophagus—carcinomatous invasion or foreign body phlegmons—from the bronchial or mediastinal lymph nodes, from mediastinal tissue, caries of vertebrae or ribs, from the stomach, liver or peritoneum. All such inflammatory processes in the pericardium are fibrinous at the start.

The most important bacteria are staphylococci, streptococcus pyogenes and diplococcus lanceolatus (pneumoniae).

Traumatic (*c*) causes include stab and bullet wounds, perforation by a foreign body from the esophagus, blunt traumata such as blows, or pressure. Doubtless, subcutaneous lesions produce a point of lowered resistance which permits bacteria circulating in the blood to become established and produce pathogenic effects. But there are also traumatic pericarditides, usually fibrinous, without bacteria (lit. Stern, Kulbs, and others).

#### HEMORRHAGIC PERICARDITIS

Blood may be mixed with the fibrinous exudate, or the exudate of 1.5 litres or more is sometimes almost pure blood.

This is seldom found in the ordinary infectious diseases, but is quite frequent in tuberculous pericarditis, in secondary tumors—carcinoma, more rarely with sarcoma—in Bright's disease and where there is a tendency to hemorrhage such as in hemophilia, purpura, scurvy, etc.

#### Infectious Granulation Tumors of the Pericardium

These are inflammatory new tissue growths which develop under the influence of specific infectious microorganisms. The product is granulation tissue (comp. p. 9) or granulomatous tissue, which has a specific pathological character depending on the respective organisms; since it appears as small or larger nodules, it is somewhat similar to true tumors (neoplasms).

1. Tuberculosis is almost always secondary to a tuberculous lesion elsewhere. There are differentiated: (*a*) miliary tuberculosis (tuberculous pericarditis) in which small nodules containing tubercle bacilli appear, often along the vessels of the pericardium, which is otherwise unchanged. Very similar nodules may be composed of carcinoma cells, or more rarely of amyloid. This form is less frequent than (*b*) Pericarditis tuberculosa which is probably the most common form of chronic sero-fibrinous, or fibrino-hemorrhagic, more rarely fibrino-purulent inflammation, and is differentiated from simple chronic pericarditis by the presence of numerous tubercles.

Quite frequently, a hemorrhagic, or pure bloody, exudate amounting to several litres is present although the author saw a simple serofibrinous exudate up to 2 litres. The tubercles are of lymphoid or giant cell type, discrete, or fused, lying in vascular, overgrown young tissue. They may coalesce into cheesy material forming thick, whitish yellow layers in the grayish red granulation tissue (cheesy pericarditis).

Scratch the superimposed fibrin layers and observe carefully the section surface to see the tubercles. Often, they are only found micro-

scopically, some between the fibrin, and some in the thickened pericardial tissue.

Regarding the forms of "pearl disease," resembling the bovine tuberculosis of animals, see under peritoneum.

In chronic tuberculous pericarditis, the pericardium, especially the visceral layers, may be thickened to 1 cm. or more.

Pericardial adhesions are very frequent, but usually less firm than those of simple chronic pericarditis, because of caseous degeneration. Calcification, see p. 13.

**Cause.**—Miliary tuberculous pericarditis may be hematogenous but usually, like tuberculous pericarditis, is lymphogenous in origin from tuberculous processes in the vicinity—lungs, pleura, lymph nodes, especially those in the anterior mediastinum.

2. Syphilis in a gummatous calloused form is rare. A granulating, scarring pericarditis may arise over gummatous nodules in the heart muscle, and may lead to firm adhesions of the pericardial surfaces.

3. Actinomycosis is usually induced by invasion from the mediastinum, from a cervical or a pulmonary lesion. In typical cases, it appears as fibrous adhesions between the pericardial layers, pleura and mediastinal tissues. In the calloused masses are cavities and fistulous tracts with yellow purulent, or jelly-like, contents which contain the peculiar colonies of actinomyces as minute sulphur granules, sometimes in immense quantities. Actinomycotic granulations are known to have penetrated the myocardium and entered the cavities and vessels of the heart.

A rare preparation in the museum at Basle (published by Munch) shows actinomycosis invading the mediastinum and pericardium from the lung, and penetrating the cavity of the right ventricle, also the large coronary vein. From the left auricle, fragments of a decomposing nodule the size of a bean, caused a generalized actinomycosis, with numerous metastases in distant muscles (arms and legs), in the skin (in the extremities and the head), in the intestines, kidneys and in one testicle (compare cases of Schmorl, Paetzold).

### True Tumors

Primary tumors of the pericardium are quite rare. In a dye worker, 35 years of age, who had chronic verrucose endocarditis, the author saw within the thickened pericardium, which was filled by 400 cc. of sero-fibrinous hemorrhagic exudate, three flaccid edematous fibrous polyps with broad pedicles. Two were located on the posterior wall, and one showed finger-like branching; the third, the size of an apple, grew anteriorly (comp. Jarisch).

One lipoma each, is mentioned by McKechnie and Struppler. The author saw a finely fibrous, pedunculated lipoma, with smooth tendon white coating almost ready to become a loose body (*corpus librium*); and another the size of a chestnut, suspended from the posterior wall of the left ventricle, which continued in the musculature as far as the atrioventricular insertion of the posterior mitral valve leaflet. In very rare cases (Klob, lit.), in pericardial lipomatosis, fat masses may tear free of their pedicles and become laminated "free bodies" (see peritoneum). The "*corpora libra*" in the pericardium are mostly hyalinized and smoothed fibrin clumps, or torn off, organized fibrin masses. They may also calcify (quite rare). Sarcomas are mentioned by Drysdale, Kaak, Tobiesen, lit. Dietrich mentions a papillary carcinoma which he thinks was derived from the surface cells.

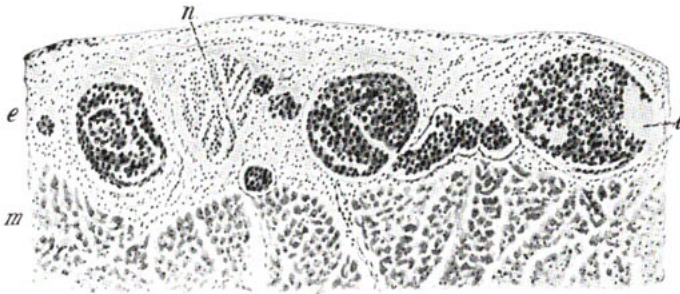


FIG. 4.—Extension of carcinoma in lymph vessels of the epicardium (carcinoma of esophagus); m, myocardium; e, cellular epicardium; n, nerve; l, lymph vessels filled with carcinoma plugs;  $\times 56$ .

Carcinomata and sarcomata are seen as secondary tumors from the vicinity or metastatic to some distant primary focus. Sometimes, carcinoma infiltration is masked by its resemblance to a soldier's spot on the epicardium, and is recognized only microscopically. If rapid invasion of a diffuse or nodular type takes place, inflammation, usually mild, is initiated (carcinomatous pericarditis). Sarcomata, especially lymphosarcomata derived from cervical or mediastinal lymph nodes, produce at times a very thick, diffuse, board-like infiltration of the pericardium, especially of the parietal layer and the parts of the visceral layers resting on the auricles. Carcinoma of the esophagus, the bronchi, or the stomach may occasionally produce the same results through the lymphatics.

Of parasites, it may be said that occasionally cysticercus, trichina and echinococcus occur.

### Changes in the Pericardial Fat

There are (a) hypertrophic, (b) atrophic conditions.

(a) Increase of pericardial fat (fatty heart) may reach a high degree leading to lobulated fat deposits sometimes as thick as a thumb, especially in obese individuals. The regions of choice are at the edge of the right ventricle, the area about the conus pulmonalis, the rim of the left ventricle, and the apex. Because the fat penetrates the muscle bundles, the subsequent atrophy of the muscle has great clinical importance.

(b) So-called mucous, or better, serous, or gelatinous atrophy of fatty tissue is frequently found in emaciated, cachectic, senile, carcinomatous, or phthisical individuals. The yellow fat is changed to a jelly-like brown substance. It is caused by atrophy of fat cells and an accumulation of edema fluid in the spaces left by the tissue destruction. The fat cells, after coalescence of the fat droplets into globules, revert into variously shaped connective tissue cells,—rounded, spindle, stellate—which lie in an edematous ground substance and contain fat globules of yellowish brown color. These cells may shrink so that they finally correspond to common connective tissue cells.

### ENDOCARDIUM

The endocardium consists of a layer of thin fibrous and elastic tissue with smooth muscle fibres, the latter especially at the conus arteriosus (Nagayo), the whole covered with endothelial cells. Between this and the heart muscle is the loose, fibrous subendocardial tissue connected with the intermuscular connective tissue of the heart itself. The valves are rich in elastic fibres.

With Browicz, we differentiate several types of tendonous fibres: (a) valvular, which are constant, (b) parietal, inconstant, (pseudo), in contact with the muscle trabeculae and against the walls, (c) intraventricular (pseudo), suspended within the ventricular cavity, and according to Huchard, if they vibrate, the cause of abnormal sounds. Besides those in the ventricles, they may be present in the right and left auricles, (see under cardiac malformations). [So-called Chiari's network is a system of coarse to fine fibres in the right auricle probably as a congenital anomaly. See Jordan, W. R., *Arch. Path.*, 1926, 2, 841.—*Translator.*]

Certain tendon-like formations of the ventricle resembling the types (b) and (c) are considered by Tawara and Magnus-Alsleben as anomalies of the atrioventricular muscle fibre system (Tawara's conducting system). Moenckeberg accepts Tawara's explanation for only certain of the so-called pseudo-tendon fibres, *i.e.*, those which contain Purkinje fibres (proof by

glycogen staining) and not for others which contain only ordinary heart musculature, or none at all (lit. by Herxheimer and Thorel).

The muscular and neuro-muscular atrioventricular system is considered by its discoverer as the sole muscular connection between auricles and ventricles, (bundle of His). However, since its function is to conduct stimuli from the auricle to the ventricle (papillary muscle area), it has been called the conducting system. It begins, according to Tawara, on the right side of the auricular septum in the vicinity of the coronary vein and while still in the septum, forms a nodular thickening, Tawara's, or the atrioventricular node. Histologically, it is formed by fusion of two divisions, from an auricular and a ventricular node with their processes. It passes through the septum as His's atrioventricular bundle which also contains non-medullated nerve fibres, (Wilson, Engel, Oppenheimer) and is surrounded by numerous ganglion cells. It reaches below the pars membranacea to the base of the ventricular septum where the trunk (*crus commune*) divides into two branches, the left being the larger, which follow the septum downward, passing first through the trabeculae to the papillary muscles where they are distributed in both chambers predominantly as a subendothelial network. These fibres are analogous to Purkinje fibres of the horse, but have a firmer and more isolated connective tissue sheath which may be injected (Aagaard and Hall); the terminal prolongations which gradually lose their special structure—their cable-like isolation—by connective tissue, fat and lymph spaces, communicate by continuity with the ventricular muscle fibres. This conducting system which differs as to its fibres from the other heart muscle by its greater wealth of glycogen and sarcoplasm, is poor in fibrillae, lacks the cross striations, the step-like gradations, the anastomoses with neighboring cells, and is in a many-meshed net-like arrangement. A very generous blood supply to the system is furnished chiefly by the right coronary artery (Haas). At the anterior border between the superior vena cava and the rest of the right auricle, lies another nodule similar to the first named, the Keith-Flack, or sinus node (Koch). According to Thorel, this has a connection with the atrioventricular ganglion by means of the fibres of Purkinje; Kulbs succeeded in demonstrating such a specific connection of the muscles in animals, but it is still undetermined in man (comp. Hubert).

While Aschoff and his pupils searched for the point of origin of the stimulus for the conducting system on the anterior margin of the opening of the coronary vein, most others see the origin of normal heart action in the sinus node.

The afferent cardiac nerves, the vagus (*moderator*), and the *nervus accelerans*, end, for the most part, in ganglion cells from which nerve fibres

emerge and freely enmesh the muscle fibres. While ganglion cells are usually absent in the actual walls and in the ventricular septum, they are arranged in groups in the bundle of His, especially in the ganglion, and the left vagus supposedly influences the stimulation in the atrioventricular ganglion while the right vagus affects the sinus ganglion (comp. L. R. Muller, Glaser).

See Moenckeberg's complete references in the lit., also Tandler, in regard to the anatomy and physiology of the bundle of His; also see Monckeberg, lit., as to its development, and its characteristics in extensive cardiac malformations.

The functional importance of this system is clearly brought to our attention in the Adams-Stokes symptom-complex with its peculiar bradycardia due to heart block. In milder degree, the ventricles beat more slowly than the auricles; in complete dissociation (auriculo-ventricular block), the ventricles and auricles beat quite independently of each other, *i.e.*, the ventricular beat is no longer controlled by the rhythm of the auricles, when the conduction of the stimulus from the auricles to the ventricles is "blocked." In a number of these cases with fainting spells, etc., it has been proved that there is a break in the continuity of the bundle of His caused by scars, gummata, calcification, etc. (lit. by Monckeberg). But incomplete dissociation is possible when the bundle of His is intact anatomically, *e.g.*, in scarring processes of the musculature which ceases to react to the special stimuli (muscular type in contradistinction to transmission type). The cause of the neurogenous or Morgagni type is peripheral (vagus), or central (medulla oblongata), in the cardiac nerve apparatus (Nagayo, see Monckeberg). But to what extent diffuse or circumscribed pathological changes in the system such as adiposis, loss of glycogen, fatty degeneration, common, or so-called rheumatic nodular infiltrations, hemorrhages, etc., can be associated with cases of cardiac weakness or of sudden death by heart failure is still an open question. Loew and Sternberg believe there is little or no relationship.

Subendocardial hemorrhages have recently claimed attention. They are frequently observed, but must involve the bundle of His alone, especially its left side (Monckeberg, and others), and thereby be differentiated from the hemorrhages in asphyxia which usually affect both the endocardium and the pleura. They are found in infections (Sternberg), especially diphtheria (Berblinger, Zum Winkel), after the administration of certain cardiac drugs (Aschoff), in tetanus, eclampsia and other convulsive conditions (Ribbert). Vagus irritation seems to be of special importance because, either in consequence of its paralysis, or because of the effect of abnormal contractions of the left ventricle, there is congestion in the remarkably rich vascular system of the bundle which might lead to

mechanical capillary tears (comp. Berblinger, lit.). Nothing more definite is known of the pathological consequences of such hemorrhages, except that fibres of the bundle of His have been found degenerated within their confines.

The fact that under certain conditions the pathological changes are confined to the bundle of His, and under other conditions, more marked anatomical changes are noted in the bundle (Monckeberg), without suggestive symptoms during life, must compel reserve in the recognition of a special pathology of the bundle of His (Aschoff) in the expectation of perhaps a "newly evolved pathology of the heart on the basis of investigations of the bundle," (see Monckeberg, Wenckebach). Tendeloo only recently voices doubts as to whether marked changes of the bundle *per se* will directly cause cardiac insufficiency (other lit. in appendix).

#### VESSELS OF THE VALVE LEAFLETS

In the soft and fleshy valves of the fetus, there are vessels, and in the auriculo-ventricular and the tricuspid valves of the newborn, they still reach to the free valve margins. In the adult, however, the auriculo-ventricular valves have vessels only towards their bases, but a productive endocarditis may bring about formation of many new vessels.

Fenestration between the margins and the free edges of the semilunar valves (lunulae) may be congenital, or occur in advanced age as a result of marked thinning—atrophic tissue loss, atrophy from inactivity,—but the author has seen it in youth also when there were congenitally large and tender valves. Beneke also speaks of atrophic fenestration. The edges of these oval or slit-like fenestra are smooth, differing from those of ulcerative processes by absence of infiltration and fibrous thickening. They cause no functional disturbances when linear holes are above the edge of closure especially when they are in the lateral part of the valves near the angles of insertion. Occasionally, quite tender auriculo-ventricular valves are also seen.

#### Simple Degenerative Conditions of the Endocardium

(a) Fatty degeneration macroscopically takes the form of white or yellowish white spots appearing especially on the ventricular side of the anterior mitral leaflet; it occurs frequently in old people, but may also develop, even in children, in anemia, intoxications and infections, and is often combined with calcification.

Microscopically, some of the cells in the spaces between the connective tissue fibres are filled with minute droplets. The "white spots" on the ventricular side of the large anterior mitral leaflet are degenerations of the connective tissue to which accumulations of fat and lime, eventually also

cell growth, are added, (Beitzke). Some speak of this as "athero-sclerosis" (Sato, lit., Anitschkow). Doubtless, mechanical factors play a part—injury of the valve during systole (see p. 42); according to Martius, (lit.), the action of poisons, infections, and also nutritional disturbances must be considered, especially in children (see experiments of Anitschkow).

(b) **Sclerosis.**—The endocardium becomes calloused, white, glassy and hyalinized (hyalin degeneration). Often an entire valve, especially the tricuspid, but sometimes only a portion at the free rim, is affected. The mural endocardium of the auricles and ventricles may show white spots and striae. A diffuse thickening is less frequent.

Hyalin degeneration is particularly prone to occur in places already changed by granulation tissue.

Microscopically, broad connective tissue fibres lie close together with very few cells between; the connective tissue, otherwise reticular, becomes compact, glassy and homogeneous.

(c) **Mucoid softening** consists of transformation of firm fibrous tissue to a gelatinous mass consisting of a mucoid background with more or less numerous embedded branching cells.

(d) **Calcification.**—Lime salt deposits (petrefaction), occur chiefly at the bases of sclerotic leaflets or those with fatty degeneration.

The lime salts are visible as grumous masses which stain deep blue with hematoxylin. That portion of the lime not visible is held in solution by protein colloids and carbonic acid in the blood and tissue fluids which saturate cells and tissues.

(e) **Atheromatous degeneration** consists of a soft necrotic disintegration of parts of the valve tissue which usually shows, in addition, the regressive changes just described. Quite frequently there is a combination of necrotic and fatty disintegration, (microscopically there is granular fatty detritus with cholesterin crystals).

(f) **Amyloid degeneration** is rare in its more advanced grades, in which the endocardial as well as the myocardial connective tissue contains macroscopic clumps and nodules of amyloid substance (Heschl, Ziegler, Wild, Beneke, Stumpf, lit.); as a rule, this change is then found in other organs also, and is rarely confined to the heart muscle (Landau); microscopically, mild forms are frequent (see Huebschmann, also pp. 41, 55). M. B. Schmidt found networks of lymph and blood vessels in the valves that were filled with amyloid material.

All the changes mentioned under (a) to (e) are especially frequent in advanced age, but are found in a milder form in earlier life also, (Moenckeberg). They affect chiefly the valves, often those that have undergone the changes that follow inflammatory processes, but may develop in the

mural endocardium of the ventricles and auricles, especially in the left. Sometimes special mechanical factors are at work; according to Zahn, friction from the blood stream is important, especially in insufficiency of the aortic valve, but pulling and pressure during opening and closing may account for the development and localization of these changes, especially those described under (a) and (b). In other cases, inflammatory residues are predisposing factors, especially those of cicatricial nature in infectious endocarditis, but the most frequent reasons are simple senile regressive changes which may appear prematurely in middle life as the result of overworked valves. A tendonous change in the papillary muscles, or of isolated chordae tendineae, (Loewenstein) is a sign of wearing out processes, (see Rossle), and is analogous to the calcification of the annulus fibrosus mentioned on page 41.

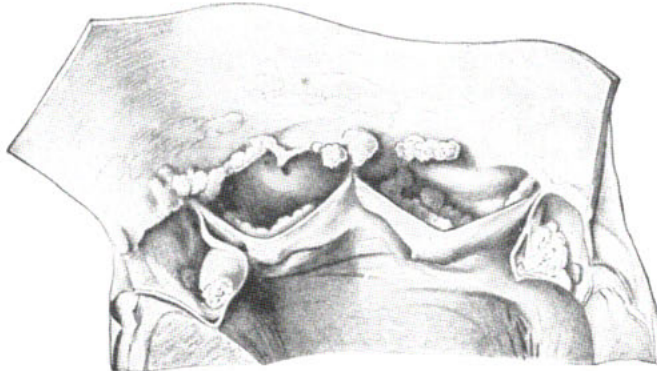


FIG. 5.—Aortic valve leaflet markedly sclerotic and calcified from an 85 year old man. Calcareous clumps deep within and at upper border of sinus of Valsalva; the valves rigid and almost immovable.

Progressive conditions, such as cartilage and bone formation in the valves, are seen much less frequently (comp. Rosenstein, Rohmer, see also Mebius, lit.).

When the degenerated or roughened areas are on the surface thrombosis may occur. The thrombus may be more or less organized by a productive inflammation, however inactive, which starts in the surrounding tissue of the endocardium.

If the process is often repeated, there result nodular or diffuse thickenings to which calcification is added.

Sclerosis and atheroma, thrombosis and calcification, rarely true ossification, produce exceedingly irregular thickenings and changes in form—sclerosis and atheroma of the valves. (See “non-inflammatory endocarditis” called by Dewitzky “thrombo-sclerosis,” Felsenreich and von Wiesner, p. 42.)

Functional disturbances result just as they do in fibrosis of the valves following infectious endocarditis. Ofttimes it is not easy to decide whether a particular case is an infectious endocarditis or a primary sclerosis and atheroma. Quite exceptional difficulty is encountered because chronic fibrous thickening of the valves induces regressive tissue changes similar to those noted under (a)-(e).

**Differential Diagnosis.**—Usually, primary regressive changes are not sharply outlined; especially in the auriculo-ventricular valves, they are often plateau-like, or distributed flat over the whole apex to be lost without margins in the adjacent tissue. They do not elect the typical places of predilection of endocarditis (margins of closure). Thus we often see calcified layers or nodular excrescences in the aorta in the depths of the pockets of the otherwise almost unchanged leaflets, or at the points where the leaflets are attached to the aorta, or at the upper border of the sinus of Valsalva; these places are where the greatest tension and pulling occur from the backflow of the blood column during diastole. An endocarditis would not localize there, but in the ventricular direction and on the auriculo-ventricular valves, where the free edges and adjacent parts undergo diffuse thickening. We often see sclerosis of the aortic valves, also, together with sclerosis of the aorta; in this case, the process extends from the aorta to the leaflets, attacking especially the margins and extending outwards towards the valve base (see, among others, also differential diagnosis p. 40).

For more details in reference to normal and pathological histology of the parietal endocardium, see *Nagayo*, also page 43.

#### **Endocarditis. Inflammation of the Endocardium**

If the term "endocarditis" is used alone, it means an infectious inflammation of the valves—valvular endocarditis. But there is also a ventricular or mural endocarditis which may localize anywhere on the inner walls of the heart. Endocarditis on the chordae tendineae is called chordal endocarditis.

Care must be taken not to confuse with signs of endocarditis, especially in decomposing bodies, the redness of the valves from blood pigment leaving the corpuscles, coloring the serum and saturating the valvular tissue; this is only a post mortem blood imbibition.

Several anatomical forms of endocarditis are described. To understand their points in common, we shall briefly sketch the origin of the inflammation of the endocardium, and how the several forms develop. We take for granted, at present, in the etiological consideration, that injurious factors to the endocardium are not uniform in nature. We shall touch upon this later. Injuries may be caused by bacteria with their

accompanying toxins, or by the toxins alone as they are evolved during infections, or likewise by any other toxic-chemical substances which are formed within the body during certain diseases that contaminate the blood—nephritis, diabetes, carcinoma, etc. We will consider the case in which endocardial inflammation is caused by bacteria circulating in the blood. What are the endocardial lesions and what are the reactive appearances? We assume that the bacteria are present in masses and form a fine, gray, granular coating on the endocardium. It is well to remember that these loosely placed masses may be easily wiped off by needless and careless manipulation of cardiac orifices during post mortem examination. The endothelium and eventually to a greater or less extent, the deeper layers of the valves undergo necrosis below this coating, and this primary change is more marked the more virulent the bacteria; their toxic products must be held directly responsible. The rapidly passing blood stream may tear off the bacteria and if the endothelium is not directly killed, it may show cloudiness, swelling and desquamation.

In certain infectious diseases such as scarlet fever, measles, etc., the cells may be stimulated to proliferation from exclusively toxic action causing intensive cell increases in the subendothelial and deeper layers; round cell infiltration and granulation tissue growth follow. Thrombi are absent in those cases in which the proliferating endocarditis is demonstrable only by the microscope (comp. Baldassari, Czirer).

Over the area deprived of endothelium, a thrombotic coating from the blood is formed which is composed chiefly of blood platelets, some fibrin and leucocytes, and some erythrocytes; this may also contain bacteria. The thrombi have the appearance of being coated with sand.

Because they consist chiefly of clumped platelets, which differentiates them from the white thrombi of the veins which are rich in fibrin and leucocytes, these thrombi are glassy, firm, and more securely attached to their bases. For this reason the blood current cannot tear them away or break them into fragments so easily.

Thrombus formation in endocarditis is secondary, and we might speak of endocardial thrombosis. Thrombo-endocarditis (Ziegler), a term used by some instead of endocarditis, leaves the relation of thrombi and endocarditis in uncertainty; it may be interpreted in a double sense, either an endocarditis added to thrombosis, or an endocarditis combined with thrombosis. We avoid this double meaning, also for the reason that thrombosis may be absent microscopically in highly infectious, as well as in certain proliferative inflammatory, perhaps toxigenous, forms of endocarditis (see Czirer, lit.).

The second phase of the endocarditis is now reached. Where there are vessels around the necrosis, a reactive inflammation sets in; where

vessels are absent, the fixed connective tissue cells in the valves multiply actively and leucocytes appear (productive proliferating inflammation). Later, vessels begin to penetrate. If the necrosis is progressive and intensive on account of numerous, or worse, highly virulent bacteria which actively penetrate the tissues, portions of the valves dissolve or become detached by active pus infiltration which spreads in the vicinity and softens the tissue. The course is subacute or chronic if the process is less intensive and less progressive, and then, in time, warty, or flat hyperplastic granulations appear on the valves.

The degree of connective tissue proliferation, naturally, is as varied as the kinds of causative factors. In non-bacterial endocarditis, the reaction is less severe than in the infectious variety.

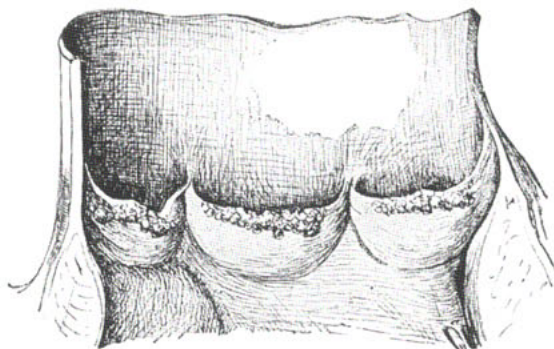


FIG. 6.—Verrucose endocarditis of the aortic valves in articular rheumatism.

Thus we see that endocarditis, like any other inflammation, is composed of these phenomena: (*a*) tissue changes which vary from stimulation, to active endothelial proliferation, (see p. 26), to very grave alterations, *i.e.*, necrosis; (*b*) exudation, and also (*c*) hyperplastic regenerative proliferation. Thrombus formation is accessory, and is conditioned by the special location of endocarditis. It is especially prone to occur in deeper endothelial, or endocardial lesions, as mentioned above; it is entirely absent in certain forms of productive endocarditis.

When there is quick destruction of valve tissue, it is called endocarditis ulcerosa or maligna; endocarditis verrucosa shows slight necrosis and is characterized by warty outgrowths of proliferating tissue.

Chronic fibroplastic, so-called fibrous endocarditis, (contracting endocarditis), is a chronic form distinguished by shrinking of the granulating valve tissue; it is often only a continuation of a vegetative endocarditis.

Accordingly we differentiate the following anatomical forms:

1. Vegetative, warty or verrucose endocarditis, (productive, simplex, rheumatic).

2. Ulcerative, malignant, necrosing, acute destructive endocarditis.
3. Chronic fibrous, fibroplastic, contracting endocarditis. Number 1 and 2, or all 3 forms may be combined.

The terms malignant and simplex are used here in an anatomical—not in a clinical—sense; the two conceptions are not identical. Clinically, the terms indicate the etiology and course of the disease, while anatomically the endocarditis found after fatal infections may be vegetative—*e.g.*, from pneumococcus septicemia, or ulcerative (malignant), (see Litten).

#### VEGETATIVE ENDOCARDITIS (WARTY-SIMPLEX) (SEE FIG. 6)

Peculiar thrombotic precipitates are formed from the blood on the injured surfaces of the valves. If the endocarditis appears in infectious diseases with known agents, the corresponding organisms are found in the early stages in the necrosed surface layers and beneath the coating of the valves which points to the hematogenous route of infection. A productive inflammation, usually showing slight leucocytic infiltration of the endocardium, is seen in the vicinity of the platelet-covered surface necroses. The fixed cells of proliferating valve tissue appear enlarged and increased, and penetrate into the coating, replacing and organizing it from below (fig. 7). At this stage, bacteria can no longer be demonstrated. New blood vessels growing from the base of the valves form capillary networks which send prolongations into the organizing nodules. Leucocytes may emigrate from these vessels. In the beginning, the nodules are translucent, resembling the old fashioned "blotting sand," pale red, and gelatinous, but as the granulation tissue changes into connective tissue, they become more opaque, grayer or whiter, and the firmer they become, the firmer they adhere to the underlying tissues. Sometimes they resemble condylomata, polyps, or rooster's combs in consequence of the abundant fibrinous thrombotic deposits.

The first fresh coating may appear flat, like a serosa freshly coated with fibrin. Then the name vegetative endocarditis is not as yet justified.

**Course.**—If the process is superficial, only the base of the coating shows organization, and everything regresses except a scar-like circumscribed thickening, often hardly recognizable (see Amster, Felsenreich and v. Wiesner). Deeper injury leads to a chronic inflammatory granulation process in the valve tissue—chronic fibrous—or better, fibroplastic endocarditis—which frequently ends in thickening and cicatricial shriveling of the whole valve. This is frequent in articular rheumatism.

Chronic endocarditis may often assume an acute character from slight causes (recurrent endocarditis).

In the fibrous vegetations, newly formed vessels remain long after cessation of all inflammatory symptoms, and according to Koester, are

predisposing factors in new bacterial growth in which emboli are frequent (see p. 36).

Caution is necessary not to interpret every grayish red coating on a changed valve, as a newly implanted endocarditis. It may be only a simple thrombotic precipitate (see p. 24).

**Localization of the Vegetations.**—They favor certain locations. On the auriculo-ventricular valves, they choose the auricular side on the thickened, often uneven, edges, or at some distance from the free edge, not rarely they are shaped like delicate wreaths. On the semilunar valves, they are usually on the ventricular side on the margins of closure, but also

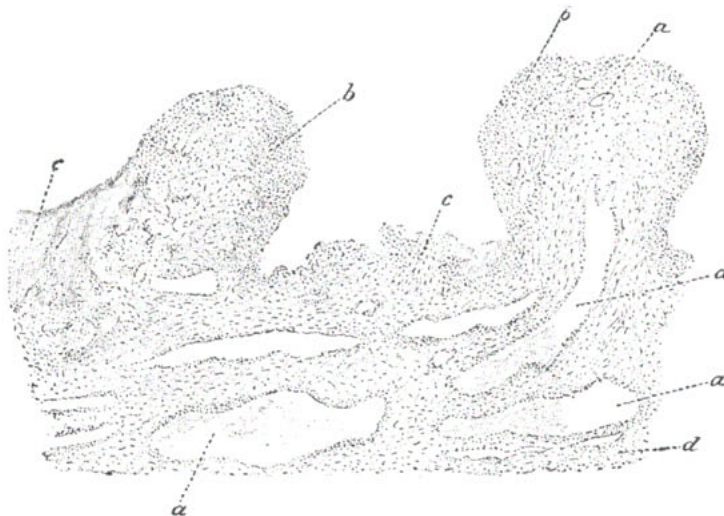


FIG. 7.—Subacute verrucose endocarditis of mitral valve after articular rheumatism; a, blood vessels; b, cellular granulation tissue; c, thrombotic masses; d, valve tissue with wide vessels; (low power).

above this point. Every region of the valve, the chordae tendinae and the whole endocardial lining may, however, become the seat of inflammation. The mitral and the aortic valves alone, or together, are the most frequent sites, the tricuspid valve is second choice. In embryonal life, the valves of the right heart, which at that time work harder, are affected more frequently, especially those of the pulmonary arteries.

The so-called noduli albini may be mistaken for vegetative endocarditis. They are found on the free rim of the tricuspid in the newborn, and are small connective tissue growths, remnants of the fetal gelatinous valve crest which disappears later. Frequently, in the newborn and even in later fetal months, there are found 3 to 6 minute, poppy seed-like, blood nodules or cysts on the auriculo-ventricular valves, (both surfaces), or

distributed over the whole surfaces. In the anterior mitral leaflet, they are only on the free edge; and they rarely occur in the aortic leaflets. They are dark red to black and project especially on the auricular side of the auriculo-ventricular valves. First they were thought to be valve hematomas (Luschka, Parrot), or hemorrhages into the soft loose valve tissue (Odzinow). Then they were taken for vessel ectasias (Berti, Koniger, Fahr, Hammes, Pepere), or even for angiomas (Nickols). On the other hand, Meinhardt (see also Haushalter and Thiry), demonstrated that these blood nodules which he calls saccular hematomas are formed by dilatation of preformed expansions on the valves, these expansions being supplied by a narrow channel-like opening lined with endothelium. Wegelin added further details, and recently Jonsson reconstructed them in wax. Wegelin, in a second work, differentiates (a) blood sacs or cysts, especially in children, rarely in adults (see also Bundschuh, Zurhelle, Wendel) starting from endothelial tubules and persisting from fetal life; (b) blood sacs developed from newly formed endothelial canaliculi in a manner analogous to valvular endocarditis, appearing in adults and which may be mistaken eventually for angiomas. The first form disappears during the first year of life; the blood breaks down, undergoes hyalin changes and organization, when the sac becomes smaller and is finally reduced to a pigment granule, or disappears entirely. Pigment can often be found in the valve tissues. The blood sacs of the second form also atrophy later. The aortic leaflets in children and adults may also show congenital thickenings separated from the free edges by a narrow margin but blending with the valve on the other side.

#### ULCERATIVE ENDOCARDITIS

Septic, malignant, diphtheritic, deeply necrotic or acute destructive endocarditis.

This form, as mentioned above, is differentiated from vegetative endocarditis by the degree, and therefore often occurs simultaneously with the latter. The selection of special areas is not so striking, and the right heart is more frequently affected than in vegetative endocarditis. Microorganisms which quickly penetrate the depths of the valve, cause rapid destruction of tissue and separation of minute and larger pieces of the leaflets; in one case there is more necrosis (pure or with fibrin), in another more pus (purulent infiltration, liquefaction, purulent demarkation), and so on. While these ulcerative lesions are forming, precipitation of irregularly formed thrombotic masses takes place like warty coverings of globular or polypoid form often penetrated by masses of bacteria (figs. 8 and 11). They may soften and wash away, or organize; the destructive process may spread towards the surface and into the depth of the valve tissue as the

bacteria invade in every direction. Perforation readily occurs, or, a semilunar valve, *e.g.*, tears through. At other times, their attachments

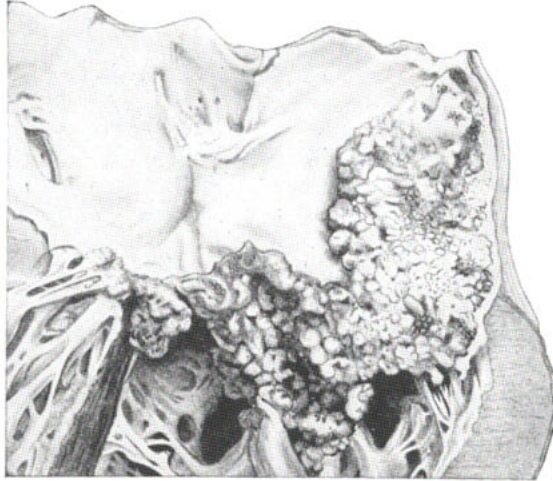


FIG. 8.—Insidious ulcerative endocarditis with marked thrombosis on the mitral valve extending to the endocardium of the auricle. Staphylococci in blood; fever and joint pains for 5 months; 18 year old student;  $\frac{5}{6}$  natural size.

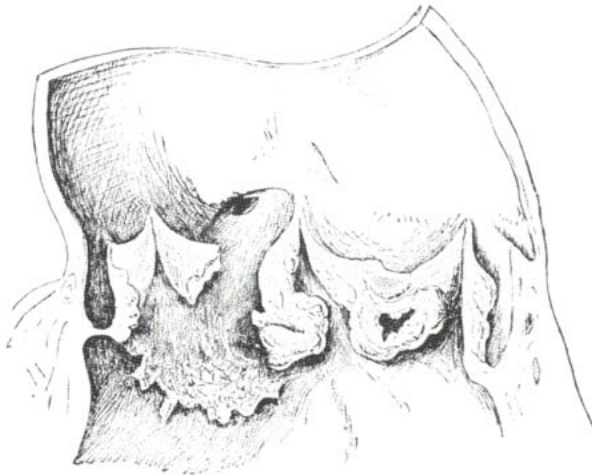


FIG. 9.—Ulcerative aortic endocarditis with acute valvular aneurysms, one of which (posterior or median leaflet) is perforated at the apex, while the aneurysmal right leaflet (r. coronary art. in the sinus of Valsalva) has torn through the middle; below, a large parietal endocarditic ulcer slightly covered with thrombi; left leaflet with entrance of the left coronary artery is divided by the cut.

are loosened or the process extends to the chordae tendineae and papillary muscles, (chordal and papillary endocarditis), and they are torn apart. The inflammation may extend by continuity to the surrounding tissue,

to the beginning of the aorta, rarely to the pulmonary artery, or to the mural endocardium, when the latter as well as the underlying myocardium may ulcerate (parietal ulcer); during this process thrombi may form again.

Isolated parietal endocarditis, as Deus (lit.) saw it in both ventricles, is very rare.

The development of ventricular or mural endocarditis is favored by floating valve tags which oftentimes have whip-like thrombi attached and whose influence may extend even to the arteries; parietal ulcers form

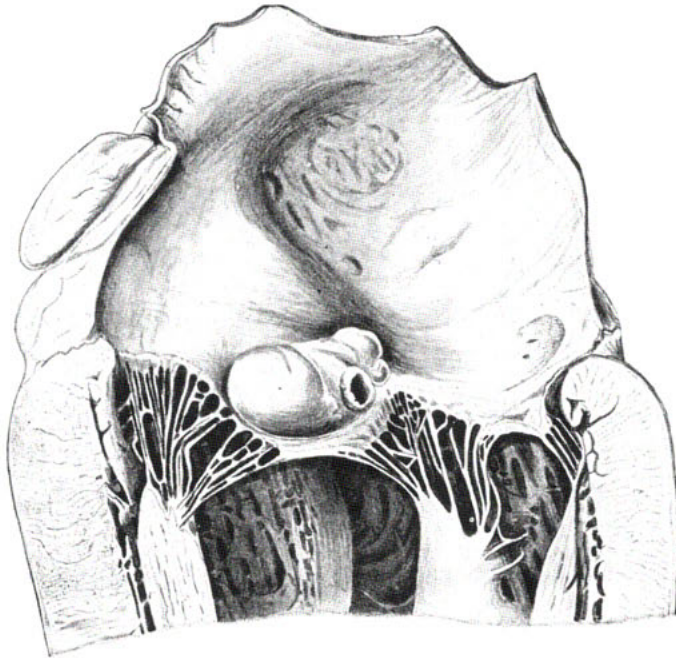


FIG. 10.—Chronic aneurysm on the aortic tip of the mitral valve perforated at a diverticulum-like projection. Above, the opened l. auricle; below, part of the l. ventricle below the divided mitral; man 30 years old;  $\frac{2}{3}$  natural size.

through implantation of bacteria and, if the thrombotic masses become calcified, they further traumatize the walls. These ulcers may penetrate so deeply that the blood pressure bulges the area outward like an aneurysm (ulcerative parietal aneurysm); there is especial danger when such a process involves the membranous septum which then bulges toward the right auricle or ventricle or toward the pulmonary arteries; thrombus formation is favored and perforation of the septum readily occurs.

Acute and chronic valvular aneurysms are very characteristic.

When a layer of the valvular endocardium is destroyed by progressive ulceration, a valvular aneurysm results. According to von Arx, throm-

botic masses and possible necrotic valvular fragments form a considerable part of the aneurysmal wall, being thrust into the sac by the blood pressure. The semilunar valves bulge toward the ventricle (fig. 9), the mitral valves bulge into the hollow of the funnel, *i.e.*, the auricle, when an ulcerative aortic endocarditis extends to the aortic leaflet of the mitral; in such cases the author saw sacs the size of beans. External thrombotic deposits aid in the thickening of the sac, but there is frequent perforation, with the torn opening growing slowly larger. In other cases the aneurysmal sac expands slowly until it reaches the size of a walnut, and then may contain thrombi or fluid blood. But perforation may also occur in this case. Very rarely a dissecting aneurysm (interparietal) develops (Pepere).

Primarily defective or misshapen valves are frequently the choice of an ulcerative endocarditis, for the friction of the margins of the aortic valves during diastole favors the lodgment of bacteria (see Kurz and Bauer, Kaboth, Beneke). In a 27 year old soldier, the author saw only two aortic leaflets with two symmetrically placed perforated aneurysms in the larger leaflet which corresponded to the normal right and posterior cusps; there was a short median line in the depth of the semilunars; the papillary muscles were absent, the chordae were inserted directly into the wall, the tricuspid was extremely thin, and the very thin pulmonary leaflets were fenestrated.

In reference to ulcerative aneurysms of the sinus of Valsalva, or at the beginning of the aorta from the progress of endocarditis of the leaflets of the aortic valve, or from possible implantation of bacteria in floating valvular attachments, see under arteries.

If an ulcerative endocarditis heals, as far as the valves are concerned, the same malformations result as discussed under chronic endocarditis.

Parietal endocarditis, seen not rarely in the left auricle and ventricle, leaves superficial or deeper tendonous scars; chordae, which were covered with masses of thrombi, may retain focal or diffuse thickenings, fibrous or smooth, or rough and calcified; torn chordae often have thick clubbed ends.

A quickly fatal ulcerative endocarditis which develops during a severe septic disease, and is rich in microorganisms may be called endocarditis mycotica maligna. The valves are discolored yellowish gray, and covered with a smeary coating. Thrombotic material is usually absent in any quantity. Defects develop quite frequently because the valves practically liquefy. Frequently, however, the general disease causes death before this can occur.

In the type called endocarditis lenta caused by the streptococcus viridans (see p. 36) there are often large numbers of phagocytic giant cells below the bacterial layer (see Orth). But the thrombotic coating may be very marked, but also very slight, as the author can verify.

Pneumococcic endocarditis often serves as an example of an infectious endocarditis with heavy globular deposits on an ulcerated base; it is



FIG. 11.—Globular endocarditis (gonorrheal); immense polypoid globular deposits on the mitral; 19 year old male; died 2½ weeks after infectious coitus (brothel); had also gonorrhoea myelitis; ⅔ natural size.

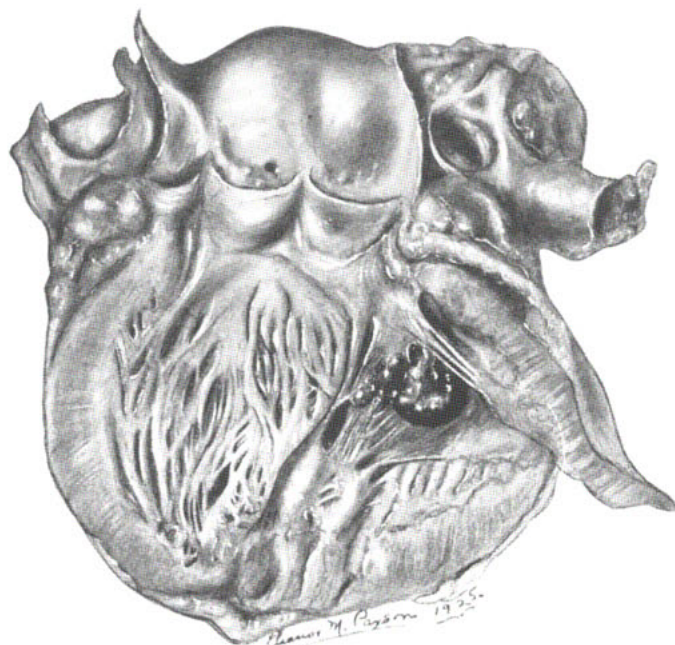


FIG. 12.—Vegetation of the mitral valve peeping out from underneath the portion of the left ventricle to the right. Present in a patient 35 years old. L. H. #67.

characterized by the unusual massiveness of the yellow green, broad-based globular thrombi on the ulcerated valves, but in the pneumococcic form the tricuspid is more frequently affected (Netter, Weichselbaum,

Kerschensteiner, Fiessinger-Rondowski). Emboli from these vegetations are often bland, but sometimes infectious. Pneumococci are often found in the vegetations, and in the organs generally, especially in the spleen which is considerably enlarged, (in one of our cases, 558 gms.); they are present also in pulmonary infarctions or abscesses, often in the involved meninges and even sometimes in the blood. We have seen this form of endocarditis in cases of pneumococcus bacteremia and pneumococcus sepsis in conjunction with pneumonia (reported by Wandel); the grayish green to yellow thrombi with smooth surfaces had a diameter up to 5 cm. on the tricuspid valves (see also Fulci). But pneumococcus endocarditis has also occurred with all the appearances of a common verruginous or ulcerative endocarditis (see Henke). And massive globular vegetations also occur in gonorrhoeal endocarditis, sometimes without much valvular destruction (fig. 11); again, in this form, a severe verruginous ulcerative process may occur, especially of the aortic and then the mitral valves (lit. by Schlagenhauser), but milder forms are better known. Beitzke would like to differentiate polypoid endocarditis from verruginous and ulcerative, but according to our opinion, this is unnecessary.

#### ETIOLOGY OF ACUTE ENDOCARDITIS. HISTORICAL. EXPERIMENTAL

Endocarditis is either a secondary affection, *i.e.*, it arises from an infectious focus somewhere in the body, as in puerperal fever, surgical wound infections, pneumonia, osteomyelitis, urethral gonorrhoea, etc.—from which bacteria enter the blood; or it is the primary localization of inflammatory factors which leave no demonstrable traces of disease where they enter the body. The former is by far the more common.

The two chief forms of acute endocarditis—verruiginous and ulcerative—are only degrees of the same condition with essentially the same causes, infectious, or infectious-toxic factors in the blood stream. But in vegetative endocarditis, the necrosis involves only the superficial layers of the valve, perhaps only its endothelium, and formation of granulations takes place from the valve itself, while in ulcerative endocarditis with the rapid invasion of organisms, there is a severe necrotic and purulent destruction of the parts involved.

In the ulcerative septic form, the demonstration of the causative organisms is not difficult. This was first done by Heiberg and Eberth. Usually, they are cocci as in severe pyemia and septicemia (staphylococcus and streptococcus pyogenes).

In vegetative endocarditis, the mycotic nature of which was first pointed out by Koester and Klebs, and which is chiefly a concomitant of articular rheumatism although also of other infections such as measles, scarlet fever, pneumonia, typhoid, etc., the findings are less certain the

older the disease, because, as Bartel emphasized, the bacteria perish. Indeed, as in articular rheumatism, the actual cause of the affection may be unknown. Possibly it is a diplostreptococcus easily destroyed and unstainable, but active through its toxins (see lit. by de Vecchi, p. 64). Koniger attempted to explain amicrobic simple endocarditis through the possible action of bacterial toxins in infectious diseases—endocarditis toxica simplex, (see also Czirer and comp. p. 26).

Besides the staphylococcus and streptococcus pyogenes (the streptococcus viridans is frequently the cause of vegetative endocarditis, Schottmuller, Reye, and more rarely of the severer endocarditis lenta in which the leaflets become ulcerated), other organisms may be at fault, such as the diplococcus pneumoniae, (5 times in 43 cases of infectious endocarditis, Harbitz), the gonococcus, even when urethral gonorrhoea is mild the distant metastasis may be marked, also *B. influenza coli*, diphtheria, typhoid, actinomycosis, etc. have been found (lit. in appendix). Tubercle bacilli probably appear only as secondary arrivals in the vegetations. A verrucose or polypoid or diffuse caseating valvular tuberculosis is very rare (Fromberg). The parietal endocardium may also be invaded (lit. by Schultze). Michaelis and Blum claim to have caused tuberculous vegetations after injuries to the aortic leaflets and intravenous injections of tubercle bacilli. De Vecchi and Bernard, and Salomon could not obtain the same results; they saw only simple inflammatory reactions—necrosis, granulations and fibrin (see also Fulei).

The organized causes of endocarditis are consequently very many, and the activity of the same organism varies according to its virulence.

For this reason, it is easily seen why the cases do not always fit exactly within the boundaries of typical vegetative or ulcerative forms, but show quite frequent transition types; we called attention to an intermediate form sometimes caused by pneumococci; and there are rare forms in which pus, even pustule formation predominates (pustular endocarditis), while in other cases the discolored smeary bacterial coating appears as described on p. 33 (malignant endocarditis).

Koster claimed that, as a rule, endocarditis was due to embolism in the valvular vessels as demonstrated by him; recently, capillary emboli with modified and weakened organisms—pneumococci, as in Rosenow's animal experiments—are suspected, but other writers, especially Ruhle, are of the opinion that the organisms carried by the blood are precipitated on the valves and became fixed as oysters in oyster beds are fixed in spite of the force of the waves; a conception which later was verified by experimental investigations.

Experimental solution of the question of endocarditis was attempted by the traumatic method of O. Rosenbach, or by chemical injury of the

valves in animals combined with the injection of bacteria (staphylococcus or streptococcus pyogenes) into the blood. Endocarditis and metastatic pus foci developed (Orth, Wyssokowistch, Weichselbaum, and others).

Ribbert succeeded in producing endocarditis without previous gross damage, by the intravenous injection of an emulsion of staphylococci grown on potatoes. When coarser substances were present, bacterial attachment was favored, probably because of mechanical injury to the delicate endocardium, and although the localization showed marked differences from that seen in man, Ribbert was nevertheless able to trace the separate phases of the process, viz., the implantation of cocci on the endothelium, its destruction, the invasion of organisms into the valve tissue and the fate of the latter. Finally a large number of workers succeeded, but, of course, only in a small proportion of the experiments, in reproducing an endocarditis with the localization typical of that in man by simple injections of bacteria (see Lissauer, Rosenow, Saltykow, lit.).

It may therefore be assumed that endocarditis in man is analogous; bacterial masses are forced against the valves, therefore they select the margins, and then they either penetrate the tissues or remain superficial and cause thrombus formation and connective tissue overgrowth. To further illustrate this conception, it may be pointed out that endocarditis selects that part of the heart which works the hardest, *i.e.*, in extrauterine life, the left ventricle, in fetal life, the right ventricle, (Rokitansky, Rauchfuss, lit. by Thorel). But in addition, Vecchi demonstrated that toxins alone are able to initiate an endocarditis by causing primary necrobiotic processes, which are followed directly by active inflammation. Fibrinous thrombi may be added secondarily, and according to the predominant factor, ulcerative or vegetative forms develop (comp. negative results by Vanzetti and Fulci; positive results by Porrini). These experiments justify the thought of an infectious-toxic and perhaps also a purely toxic endocarditis—which latter would justify the conclusion that other chemical noxious substances may cause an endocarditis (Königer) *e.g.*, in diabetes, nephritis, carcinoma. etc. For the present, however, it is impossible to pronounce judgment (comp. Panichi and Guelfi, and Panichi and Varni who report endocardial changes, thrombi, hemorrhages, following infusions and suspensions of carcinoma material, while Fulci, lit., and Panichi emphasize that this does indeed cause lesions, but not true endocarditis).

**Translator's Remarks.**—The form that has come to be known chiefly by clinicians as “subacute bacterial endocarditis” is anatomically a variety of verrucose endocarditis, but certain views merit attention. Libman would call it “subacute streptococcic

endocarditis" since in the great majority, anhemolytic streptococci are found when organisms are present at all; in a few cases *B. influenzae* are found and in a very few cases, other organisms. The duration of the disease is from a few weeks to two years, death resulting from exhaustion, anemia, sepsis, cardiac decompensation, uremia, etc. A characteristic symptom is the appearance of the so-called Osler's nodes—painful swellings to the size of a pea or larger on the fingers, toes, hypothenar and thenar eminences. At autopsy, the vegetations are coarse and found on the mitral valve, or extending to the mural endocardium, more rarely in other situations. During a septicemic stage, they consist in large part of bacteria; during a bacteria-free stage, healing may occur but usually so much damage has been done that the result is also fatal. The kidneys show various stages of chronic glomerulo-nephritis, but a more characteristic lesion is the discovery of partial, less frequently total infarction of isolated glomeruli. The other changes are secondary to anemia, cardiac decompensation, etc. See Libman *Med. Clin. N. A.*, July, 1918, Practical Lectures pub. by Hoeber, N. Y., 1923-24, pp. 246-274. Clawson, B. J., *Arch. Int. Med.*, 1924, 33, 157, Clawson, B. J. and Bell, E. T., *Arch. Int. Med.*, 1926, 37, 66. For the kidney see Baehr, G. L., *Exp. Med.*, 1912, 15, 330; *Am. J. M. Sc.*, 1912, 144, 327; *Arch. Int. Med.*, 1921, 27, 262.

#### CHRONIC FIBROUS ENDOCARDITIS (BETTER, FIBROPLASTIC)

This results from an acute, principally rheumatic, endocarditis, and is a chronic inflammation with connective tissue production and subsequent contraction, (endocarditis retrahens); when it finally disappears, scar tissue remains. It is essentially a consequence of acute endocarditis, and leads to valvular thickenings, adhesions, shrinkings, and to mural scar-like thickenings, or superficial or deeper tendinous scars (parietal endocardial fibrosis).

There is always a new growth of vessels at the valve base as demonstrated by Ribbert by injections.

It is rare to have a diffuse chronic fibrous parietal endocarditis with cicatricial change of the inner surface, especially of the left ventricle, without valve changes such as dilatation and thrombosis (Baumler). But a thickening of functional origin, the so-called functional elastic parietal endocardial fibrosis, as a result of increase of blood pressure in contracted kidney, etc., is quite frequent; (see Hertel, see also p. 46 and thrombogenous parietal fibrosis from capillary thrombi). A superficial verrucose endocarditis may soon heal without trace (see p. 28), but if the

inflammation extended into the deeper layers and involved larger areas, connective tissue proliferation is likely to result, because the necrotic bits and possible thrombotic deposits act as chronic irritants and stimulate the proliferative process. If an ulcerative endocarditis heals, it is accomplished only by an active and continued connective tissue proliferation sufficient to cover the extent of the necrotic, ulcerative, and thrombotic changes. This must lead to thickening, shrinking, adhesions, and fibrous organization of thrombotic deposits which in a word means a deformity of the valve, perhaps only of a single leaflet, but often to an extent that the valve is hardly recognizable. It is especially in these cases that the parts turn yellow and become stony hard from petrification, (p. 23), or even true ossification.

It may also happen that two leaflets fuse into one, which must not be mistaken for a congenital defect, especially if the latter chances to show inflammatory lesions (see pp. 33 and 97).

If one or more new acute infectious processes occur during the course of chronic endocarditis, it is spoken of as recurrent endocarditis. Bacterial implantation is favored by this place of lowered resistance and also perhaps by the newly formed vascularization, (superficial in the one case, and intravascular in the other).

Chronic valvular endocarditis is met most frequently in the mitral and aortic valves, more rarely in the tricuspid and pulmonary, and sometimes in all the valves.

The changes consist of adhesions of the leaflets, most frequently of the tricuspids, or retraction and shortening. The mitral becomes a short, thick-walled, stiff funnel, with a slit or sickle-shaped opening; the ostium is stenosed and there is insufficiency. In the semilunar valves, retraction is most frequent. The leaflets of the aortic valves become rolled inward, thickened, stiffened, insufficient, or the ostium becomes stenosed, but they also may adhere to each other, especially at the angles, or to the wall of the aorta. A cylindrical, club-like or spindle-shaped thickening or adhesion of the chordae tendineae is very frequent, but an inflammatory right or left conus stenosis is rare (lit. by Dilg).

To understand the final diffuse cicatricial change, especially of the mitral valve in rheumatic endocarditis, it must be pointed out that a large part of this valve fibrosis is secondary, that it is due in part to the function of the changed valve, and to the increased blood pressure caused by its insufficiency (Adami, see also Beneke). Secondary parietal endocardial fibrosis and fibrosis of the papillary muscles may also be found under these conditions (see p. 46).

Very often there appear on the fibrous valvular thickenings whether due to endocarditis or secondary, regressive changes (discussed, p. 22)

resembling sclerosis and atheroma of the arteries; even ossification may occur (see Rohmer).

As mentioned above, thrombotic masses may be deposited so that recurrent endocarditis is simulated, or, on the other hand, it is easy to overlook a primary simple degenerative change of valve tissue with its concomitant and subsequent consequences. The differential diagnostic difficulties as mentioned on p. 25, must again be pointed out, *i.e.*, the distinction between an older primary degenerative change of the endo-

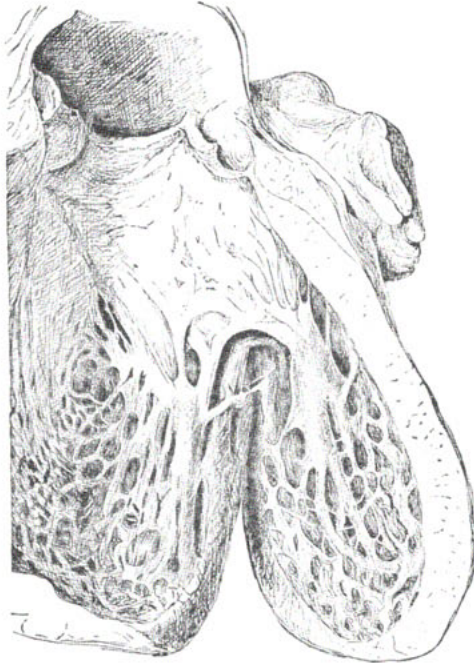


FIG. 13.—Stenosis and mitral insufficiency due to endocarditis. Mitral leaflets thickened web-foot-like adhesions of the thickened chordae tendineae; fibrous transformation of the tips of the papillary muscles; contraction of the aortic leaflets due to fibrous endocarditis; insufficient aortic valve; dilatation of the left ventricle; dilatation of the tip; flattening of the trabeculae; upward movement of papillary muscles; the plump left auricle is filled with thrombi.

cardium of the valves and a healed endocarditis with connective tissue thickening. The chief difficulty is due to the reactive proliferating processes following degenerative changes, especially if thrombi are deposited, for sclerosis and nodular thickenings are produced to degrees sufficient to cause functional disturbances. On the other hand, regressive changes often occur in the connective tissue of a valve which was thickened by a previous endocarditis but, on the whole, the less degenerative change in the connective tissue, the more its development is suggestive of chronic endocarditis. (Histological criteria of inflammatory thickening of valves

by Felsenreich and v. Wiesner, lit.; see also Czirer; also Felsenreich and v. Wiesner in reference to peculiar histological degeneration pictures—skein and loop formation on the valves in chronic endocarditis (for differentiation on the basis of localization see p. 25.) [See also Clawson, Bell, Hartzell, Am. J. Path. 1926, 2, 193.—*Translator*.]

Calcification on the fibrous ring (annulus fibrosus) surrounding the aortic and the mitral ostium is independent of endocarditis but is seldom present in large amounts; in endocarditis however, it may become a chalk ring as thick as a finger, reaching to the musculature as a nodular, continuous or beaded deposit. Bone may also be deposited (heart bones). The author saw such a case in which a broad prolongation penetrated the musculature for several centimeters and bulged through the posterior wall of the ventricle under the epicardium.

For amyloid endocarditis, see Goldzieher; also pp. 23 and 55.

#### CONSEQUENCES OF ENDOCARDITIS

The most important consequences of endocarditis are: 1. emboli; 2. valvular lesions.

#### EMBOLI

They may be (*a*) infectious, washed off from the valves in ulcerative endocarditis, reaching the lungs from the valves of the right heart, and the greater circulation from the left valves and thus be carried to different organs—heart muscle, pericardium, spleen, kidneys, eye, perhaps with occlusion of the central retinal artery (lit. Kober); they may enter the arteries of the legs, skin, etc. and be followed by metastatic abscesses, (embolic septic pyemia), in fact, any organ may be involved. Frequently, the emboli are small (capillary) and consist only of organisms which actually flood the organs. They are easily demonstrated in the glomeruli of the kidneys. In ulcerative endocarditis, innumerable punctate hemorrhages appear in the skin (hemorrhagic exanthema), the internal organs, serous membranes, kidneys, brain, retina. They are considered due partly to toxic influences. Among others, Simmonds describes brain hemorrhages due to embolic aneurysms.

(*b*) Non-infectious or bland emboli are usually released in vegetative endocarditis, by the detachment of bacteria-free thrombi; these produce simple mechanical vessel occlusion (ischemic necrosis, infarction), but it must be remembered that non-infectious infarcts may occur from even severe ulcerative endocarditis (Lenhartz).

Large emboli are capable of occluding large vessels, particularly when they consist of detached tags of ulcerated endocardium.

Detached pieces of calcified thrombi cause peculiar lesions when they enter vessels as emboli (see embolic aneurysm).

#### VALVE LESIONS (HEART FAILURE)

Organic valve lesions produce functional disturbances (stenosis and insufficiency) of the valvular mechanism and are due to both endocarditis (infectious or non-infectious), acute or chronic, and purely degenerative processes (p. 22). But in addition to these, and congenital valve lesions, we must call attention to the tearing of leaflets and muscles from intensive physical exertion or trauma, such as blows, falls, pressure, etc., (lit. by Stern, Rimbaud, Kulbs, Steinitz, Schwartz, Beckhaus, Berblinger). Functional disturbances in rare cases are due to tumors.

(a) Stenosis is the result of such chronic conditions as fusion of the margins, hardening from calcareous infiltration of thrombi, and shortening of valves; it rarely develops in the acute lesions, but abundant excrescences and thrombi may partly obstruct the opening.

(b) Insufficiency, valvular insufficiency, incontinence, inability to close, may be acute or chronic: acute, from tearing of chordae tendinae and from perforation of leaflets; chronic, as a result of scar retraction,, shortening, rolling inward, fibrous induration, (the valve becomes stiff), adhesions of the segments with the ventricular or vascular parieties; deposits and attachments, acute or chronic, may also prevent closure of a valve.

(c) Stenosis and insufficiency are often combined, especially in chronic valvular lesions, since the same factors may prevent both opening and closure.

In so-called relative valvular insufficiency, there is no anatomical change in the valve itself, (or, at least, not necessarily so); its end results are similar to those of organic insufficiency. Its direct cause is a widening of the valve ostium; the valves retain their original size but are too short to close the enlarged lumen. It is most frequent at the tricuspid, which normally, hardly permits admittance of three fingers; next in frequency, it occurs at the aortic valve.

Valvular insufficiency (muscular insufficiency) chiefly of the venous openings, more rarely the aortic, is due to faulty ventricular or papillary muscular contraction as from fatty degeneration, scar formation in the musculature, or insufficient nutrition as in chlorosis and anemia.

These are the cases in which perceptible sounds during life suggest the probability of valve changes, which, however, are not found at autopsy. The reverse may also happen, the presence of severe valvular changes, e.g., extensive vegetations, or typical old changes, (functionally healed endocarditis? Amsler) may not give the slightest auscultatory symptoms.

The most active factor in closing the leaflets of the auriculo-ventricular valve is the musculature itself, because the leaflets form a narrow funnel with lateral foldings and do not function as a sail, but as a tube valve (Koster). According to Hesse and Krehl, the valve leaflets bend and bulge into the auricle during systole in such a way as to close it above, and their lower edges are forced flat together. According to Magnus-Alsleben, the large anterior mitral leaflet acts in conjunction with the wall of the septum almost as a discharging tube or communication between the ventricle and the aorta. According to Nussbaum, the closing of the mitral valve (formalin fixation in systole) is caused by forward bulging between the chordae tendineae. The so-called senile thickening consists of a fixation of this systolic bulge.

Relative insufficiency of the aortic valves occurs from arteriosclerotic weakening and distension (aneurysm) of the aorta and also from idiopathic cardiac hypertrophy.

Both relative and muscular insufficiency regress if the musculature is able to recover.

#### ANATOMY OF THE VALVULAR LESIONS

##### MITRAL LESIONS

(a) **Mitral Stenosis (Fig. 13).**—The left atrio-ventricular ostium of adults usually admits 2 fingers; its circumference is 10 cm.; when it is narrowed, the passage of blood is hindered from the left auricle into the left ventricle (diastolic sound of varying intensity); the blood is dammed back into the auricle which it distends, and stimulates to compensatory hypertrophy. The distension may be enormous; the left auricle reaches around behind the right auricle forcing the right lung outward; its cross section may measure 20 cm., and the sagittal section, 14 cm. In the case of G. Muller, it contained 2.5 and in Minkowski's case, 3 litres of blood. The left recurrent nerve may be compressed and paralyzed (Alexander, Stoerk, Schuberth and others). Its relation to the esophagus is discussed under esophagus.

This damming back extends from the left auricle through the valveless pulmonary veins, to the pulmonary capillaries which are convoluted from overfilling; in cases of longer duration, red induration of the lung takes place, the congestion extending to the pulmonary arteries and to the right ventricle. The latter dilates, and attempts to compensate lead to its hypertrophy. Its inability to empty completely is transmitted to the right auricle possibly causing relative insufficiency of the greatly stretched tricuspid; then during ventricular systole, some blood flows back into the auricle. This damming back can be felt from the right ventricle to the most distant veins of the body (cyanosis of the ends of the fingers).

In slight degrees of stenosis the overfilling of the left auricle causes no lesions as long as the right ventricle overcomes the resistance by compensatory hypertrophy. For this reason, mitral stenosis may be endured for many years without great disturbances. But in severe stenosis or failure of compensation of the right ventricle, the left ventricle receives less blood, its work is diminished, the muscle atrophies, and the ventricle, as a whole, becomes smaller. (It does not atrophy, according to Wideroe; for this

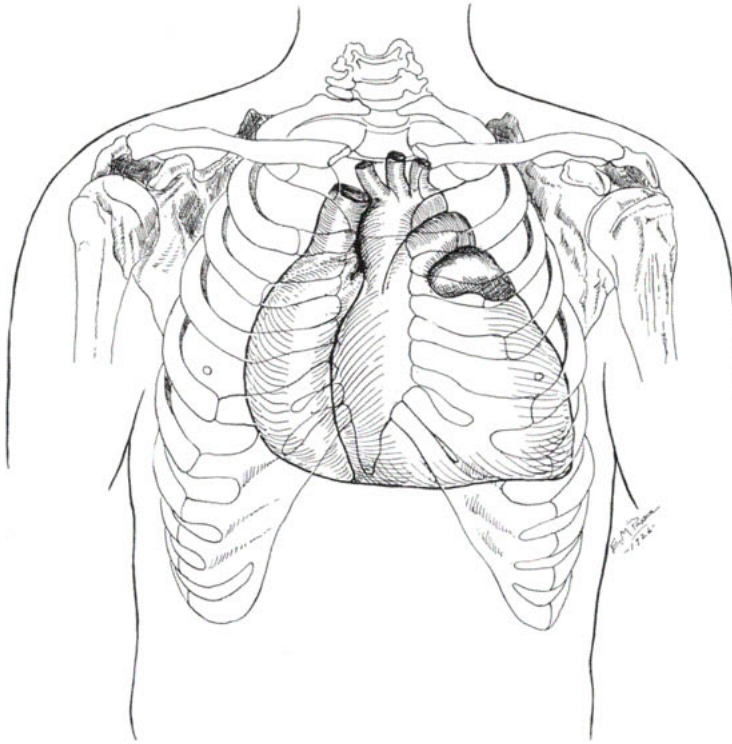


FIG. 14.—Diagram showing the relative size of the heart and thorax in acute dilatation. This happens to be in a patient with mitral stenosis but may well illustrate the dilatation which occurs in other valvular defects. L. H. #119.

disputed point, see Lenhartz, Baumbach, Oestreich, and lit. by Thorel.) [For the surgical treatment of mitral stenosis see Cutler, E. C.; Levine, S. A.; Beck, C. S.; Arch. Surg. 9, 689, 1924.—*Translator.*]

(b) **Insufficiency of the Mitral Valve.**—During the systolic contraction of the left ventricle, blood flows backward into the left auricle through the insufficient valve (blowing systolic sounds). Because the latter receives more blood than usual, it dilates, and the effect is finally transmitted to the right ventricle which also dilates and hypertrophies as in stenosis.

But the left ventricle reacts quite differently. During each diastole, it receives the blood dammed back in the overfilled auricle and is thus distended and hypertrophic, (comp. Shaper; hydrostatic test:—open left ventricle at its apex, carry in rubber tube to fill with water, compress the aorta, examine mitral leaflets from the opened auricle).

Thus all parts of the heart are dilated and hypertrophic.

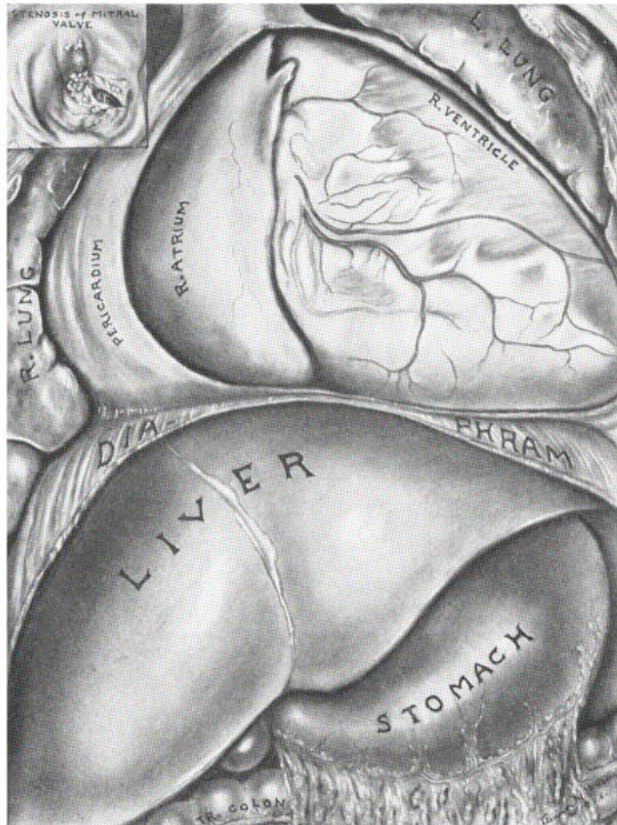


FIG. 15.—Acute dilatation of the heart with mitral stenosis showing the size of the heart and its relationship at the time of autopsy. L. H. #119. Man, 24 years old.

(c) **Stenosis and insufficiency** are very frequently coincident in the mitral valve which usually shows chronic changes.

#### LESIONS OF THE AORTIC VALVE

Normal width of the opening is 7 cm.

(a) **Stenosis**, (rarely pure), increases the work of the left ventricle which must force the blood through a narrow ostium (loud systolic murmur). The blood is thus dammed back in front of the valve. This causes

hypertrophy of the left ventricle only; if its musculature is powerful, it assumes an ovoid shape and bulges into the right ventricle which is like a flat appendix to the heart. When the left ventricle ultimately dilates, there is prompt damming back of blood into the left auricle and from thence into the lesser circulation, while the greater circulation receives less arterial blood than normally (anemia of the brain).

By subvalvular stenosis of the aorta is understood the formation of a fibrous stenosing ring about 2 cm. below the valve, attributed to a fetal endocardial thickening, (Jagic and Schlagenhauer, lit.).

(b) **Insufficiency (Fig. 13).**—During diastole the blood flows back into the left ventricle, through the insufficient valve of the aorta (diastolic blowing sound); the ventricle dilates and hypertrophies; similarly, the aorta, which of course contains a larger volume of blood during systole, also dilates. In this way, very marked cardiac enlargement is brought about (cor bovinum).

As a result of the increased pressure during systole in stenosis, or from the impact of the regurgitating blood stream in insufficiency, calloused, crescent-shaped ridges or folds (regurgitation scars), or "pockets" develop in the endocardium of the left conus arteriosus (Zahn), which occasionally expand like semilunar valves (Schminke) but with no suggestion whatever of functional adaptation or purpose (see Wilke, Steinitz, Rosenbusch, lit. Dewitzky). These structures were considered by Sotti as partly congenital in origin. Syphilitic aortitis is often accompanied by aortic insufficiency from either bulging, shortened, thickened, stiff valves or by reason of relative insufficiency from dilatation of the aorta. Adlmüller (lit.) found that 74% of cases of aortic insufficiency were due to lues. Further details under aortic syphilis.

#### LESIONS OF THE TRICUSPID VALVE

The normal width of the ostium is 12 cm.

Organic changes, stenosis or insufficiency, are very rare compared to relative insufficiency (see p. 42). Stenosis is rarely very marked (see Brieger, lit.).

#### LESIONS OF THE PULMONARY VALVES

The normal diameter of the ostium is 8 cm.

Stenosis and insufficiency are mostly congenital; the former is far more frequent.

#### FREQUENCY OF THE DIFFERENT VALVE LESIONS

Mitral lesions, chiefly insufficiency, constitute almost  $\frac{2}{3}$  of all valvular lesions; next in frequency are those of the aortic valves, especially insufficiency—then combined lesions of both valves, and eventually of the others

also. But other heart lesions are much less in number. Comparatively, the most frequent of these is relative insufficiency of the tricuspid consequent to mitral lesions. Mitral lesions are perhaps more frequent in women; lesions of the valves of the aorta (which are more chronic), are more frequent in men.

#### CONGENITAL HEART LESIONS

(Chief symptom: congenital cyanosis, see p. 90 and following.)

They are rather rare; the most frequent are stenosis or atresia of the pulmonary artery, and lesions of position of the septa, and of the large vessels.

#### RELATION OF CARDIAC VALVULAR LESIONS TO PULMONARY TUBERCULOSIS

Congenital stenosis of the pulmonary arteries is a predisposing factor in pulmonary tuberculosis. Left heart lesions combined with pulmonary venous congestion, offer a relative pulmonary immunity to tuberculosis (other details, under congestion of lung).

#### CONSEQUENCES OF VALVULAR LESIONS

(a) Abnormal distribution of blood, *i.e.*, damming backward (excess of blood) in front of (in regard to the direction of the blood stream) the diseased valve, occurs in stenosis because all of the blood cannot pass through the narrowed opening,—while an incompetent valve allows regurgitation.

This stasis extends backward until a valve interferes, *e.g.*, from the left auricle through the lungs to the right ventricle. Behind the diseased valve there is anemia which continues onward into the arterial system, while hyperemia is present in the venous system.

The results of lesions in the right and left heart differ in that the anemia in the former extends through the pulmonary artery forward into the aortic system, while in the latter, it does not affect the lesser circulation. In the right, damming back involves only the territory of the cavae, in the left, it also includes the lungs.

(b) **Changes in the Diameter of the Cardiac Chambers.**—Damming back of the blood stream causes dilatation in front of the valvular lesion, while the part behind the valve is not sufficiently filled because of the narrowed orifice (eventual diminution in size of the cavity).

As the cardiac energy diminishes, parietal thrombi are occasionally deposited in the dilated chambers (see under myocardium).

(c) Changes in the thickness of the walls consist of (aa) thinning from distension through excessive filling, or atrophy from constant decreased filling (this is disputed, see under left ventricle in mitral stenosis); (bb)

thickening, compensatory hypertrophy occur when there is greater difficulty in emptying the overfilled cavities but there must be a musculature capable of compensation; as soon as this is accomplished, abnormal distribution of blood ceases.

2. Consequences to the whole organism appear as soon as compensatory disturbances occur.

The most spectacular change is congestion with cyanosis. This involves:

(a) The lesser circulation with red induration of the lungs, "herzfehler" cells in the sputum, hemorrhagic infarction, bronchial catarrh, pulmonary edema, etc. Cardiac cases frequently die from pulmonary edema.

(b) The greater circulation in which there is general cyanosis, cyanotic atrophy of the liver, cyanotic induration and later atrophy of the spleen and kidneys, (albumen-containing "cardio-renal" urine), hemorrhagic endometritis, finally hydrops of cavities, and edema, especially of the legs.

(c) The portal system (ascites, gastric and intestinal catarrh).

In congenital right heart lesions there occur the highest degrees of cyanosis.

Emboic processes may appear in the peripheral parts and in the internal organs such as lungs, spleen, kidneys, brain, etc., (see p. 41).

[For acute endocarditis following war wounds, see Karsner, H. T., Arch. Int. Med. 22, 296, 1918.—*Translator.*]

#### MYOCARDIUM

**Anatomy.**—The protoplasm of the closely connected syncytium forming the heart muscle fibres is partly differentiated into cross striated fibrillae, but the greater part lies chiefly in the fibrillary axis and remains as undifferentiated sarcoplasm. Within this, lies the nucleus; its size and chromatin content vary, and its flat cylindrical, wavy form changes with systole and diastole (lit. in appendix).

Prolongations radiating from the sarcoplasm between the fibrillary bundles constitute the longitudinal striations of the muscle fibre. According to Hoche, M. Heidenhain, and others, there is also an exceedingly delicate sarcolemma most difficult to stain; this is disputed by v. Ebner, while Schaffer speaks of a fine membranous network passing between the fibres. The muscle fibres show straight or step-like graded lines running transversely. Formerly the opinion prevailed that these were "cement lines" of muscle cells (see also Ehrenfried, Albrecht), then artefacts or post mortem atrophy contractions were spoken of (v. Ebner, Stamer, Aschoff, Sapegno), but Heidenhain viewed them as insertions to serve lateral growth. According to Dietrich, (lit.), the cross striations are a

sort of thickening, a bunching together of fibrillae so that they can exert their power by pulling; this opinion is shared by Ogata who found the striations in the fibres of the bundle of His also. v. Ebner, abandoning his older theory, now considers the "shiny lines" special differentiated fibrilla sections corresponding in the relaxed fibre to an especially marked insertion disc, and in the contracting fibre to an exceptionally thick contraction strip which develop in the course of extrauterine life as an important functional adaptation for the regulated contraction of the muscle fibre network. They are absent in the heart of the newborn. Compared to other cross striated muscle, heart muscle fibres have the characteristic short oblique or diagonal anastomoses of the fibres, the central nucleus, the finer cross striation, and last, but not least, the cross lines (cement lines).

For more details as to difference in the muscle fibres of the auricles (less marked striation, more sarcoplasm, larger nuclei, less pigment, and greater abundance of connective tissue) see Aschoff-Tawara, v. Palczewska, etc.

See Berblinger in reference to glycogen of the heart and its distribution, and Rainer, for the lymphatic system of the heart.

### **Parenchymatous (Muscular) Diseases of the Heart**

#### ATROPHY OF THE HEART MUSCLE

There may be differentiated: simple atrophy, a regressive nutritional disturbance in which the muscle fibres become smaller so that the size of the heart as a whole is diminished; a typical example is "brown atrophy" in which the smaller fibres are markedly pigmented and the muscle appears brown macroscopically.

Both changes are found in inanition, in death by starvation, or in hunger atrophy in both its narrow and broad meaning; the food is either not supplied, or however abundant, is not able to replace the metabolic losses. The nucleus may also be smaller, (comp. Heitz), as in various cachexias such as in neoplasms, especially carcinoma, phthisis, etc. Brown atrophy is found especially in the aged and is a symptom of senility. In an 18 year old girl with extreme stenosing fistulous intestinal tuberculosis, the author saw a heart weighing only 100 gms.

But according to Wideroe, the other tissues, musculature and organs, are affected by senile atrophy to a more marked degree than the heart.

The pigment, microscopically yellowish brown, lies in the form of granules in the sarcoplasm at the poles of the nuclei. Spindle shaped figures around the nuclei are formed at the poles from deposits of pointed pigment masses (fig. 16). This pigment does not give an iron reaction.

Its origin, like that of normal muscle pigment, is possibly from nuclei products; it is usually classed with the fat-containing so-called waste pigments (Lubarsch). According to Ribbert, it is the slag of the combustion processes of the protoplasm, but Schmidtmann thinks it is a sulphur-containing melanin derived from protein, and the fat in the granules (fat stain) is only an admixture; therefore it is not lipofuscin, but melanin, similar to the pigment of brown atrophy of the liver; (see under liver for other opinions).

For iron-containing pigment in muscle fibres and interstitial tissue, see J. D. Freiswerk—also for hemochromatosis (comp. pigment cirrhosis of the liver).

Slight microscopic degrees of brown pigmentation are found even in children, but there is no atrophy.



FIG. 16.



FIG. 17.

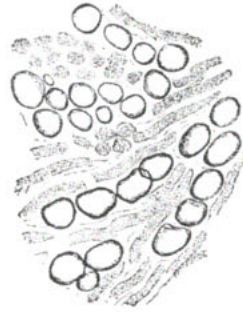


FIG. 18.

FIG. 16.—Brown atrophy of the heart; pigment accumulation at the nuclear poles; isolated pigment granules scattered in the fibers; (med. magn.).

FIG. 17.—Fatty degeneration of the heart (med. magn.).

FIG. 18.—Fat infiltration between fibers of heart muscle which have been forced apart and became atrophic; fresh, unstained (low power).

In the excessive degrees of pigment atrophy the granules may be scattered within the muscle fibres, or between them, in which case they probably originate from destroyed fibres. The connections of the muscle fibres appear loose and the "cement lines" become more distinct.

Macroscopically, the heart of brown atrophy is small, often markedly so, ( $\frac{2}{3}$  to  $\frac{1}{2}$  of normal). The apices of the papillary muscles show fibrous change; Kirch describes a "slipping down" of papillary muscles, especially the left, and shortening, narrowing, and pointing of the intrapapillary spaces. In marked degrees of atrophy the coronary arteries are usually contorted because they are too long for the small heart. This is to be distinguished from the lengthening and contortion of the coronary arteries in arterio-sclerosis (aneuryma cirsoides).

The epicardium and endocardium are not infrequently wrinkled and thickened. The color is dark brown or chestnut, the consistency normal,

or, more frequently, increased and tough. When fatty degeneration is added, the heart is soft and fawn colored.

If the heart was formerly hypertrophic, it may still be of considerable size, notwithstanding brown atrophy. The senile heart hypertrophic from emphysema or arterio-sclerosis, or even without these, (the large heart of a sturdy old man) often shows slight brown atrophy in its hypertrophic musculature (see also *Ribbert*, and p. 72).

#### PARENCHYMATOUS DEGENERATION, CLOUDY SWELLING AND SO-CALLED FATTY DEGENERATION

Microscopically, cloudy swelling produces a cloudy gray appearance of the muscle substance, due to innumerable minute protein granules which have the appearance of dust, while the cross striations of the thickened fibres completely disappear.

This change can be well observed only in fresh, unstained preparations, and by addition of 1% acetic acid, and potassium or sodium hydroxide, the clear granules swell and dissolve and so disappear, (protein-reaction), while the nuclei stand out more sharply.

This condition accompanies high fever, especially in the infectious diseases (sepsis, diphtheria, scarlet, typhoid, etc.), and various poisonings, grave anemias, etc. Macroscopically, the heart muscle has a lighter, spotted, grayish brown, opaque (cloudy), appearance (normally shiny), especially the inner layers, and is relaxed, softer, somewhat friable and easily torn.

Care must be taken not to confuse this with post mortem clouding without swelling, but with fragility of the heart muscle. This latter is a coagulation process. If decomposition is rapid, the heart muscle becomes quite friable, is brownish yellow, or, by imbibing liquids, dirty brownish red, is filled with decomposition bubbles and the heart cavities are markedly distended by gas formation in the blood. The valves and the beginning of the aorta are discolored, (sanguinous imbibition), (see p. 25).

In the so-called fatty degeneration (fig. 17) which may follow cloudy swelling or appear independently, highly refractile granules and droplets of fat of varying sizes appear in the muscle fibres, at first isolated, later more abundantly, finally causing complete disappearance of cross striation and nuclei. The degree of fatty degeneration varies considerably (see p. 53).

The fat granules are first arranged in parallel rows in both the longitudinal and transverse directions (mild degree), but as the disease becomes more severe, the latter arrangement is more and more obscured, although



FIG. 19.—Papillary muscle with fatty degeneration.

the longitudinal arrangement may remain. The so-called cement lines are very plain. In the most advanced degrees, the fat droplets are large, reaching the size of an erythrocyte, or a leucocyte, and every geometric arrangement disappears, but the nuclei are still demonstrable by the addition of acetic acid.

**Reactions to Fat.**—The shining droplets are insoluble in acid and alkalis, but a 0.5% potassium hydroxide solution dissolves the contractile substance and causes the fat droplets to stand out better by contrast.

Fat dissolves in ether and alcohol, stains brown to black with a 2% aqueous solution of osmic acid, red with alcoholic solutions of sudan. Sudan stains neutral fat and fatty acids red, the latter with a somewhat brownish tinge. Nile-blue sulphate stains neutral fat purple, fatty acids indigo blue, lipoids reddish blue to violet (see Stheeman). In fat-protein combinations in which chemical analyses can demonstrate fat, the micro-chemical staining reactions fail (see also p. 53).

Macroscopically, the heart muscle first appears spotted, then diffusely yellow, although some areas, but without definite localization, are changed more intensively. According to Goebel, the most markedly degenerated parts of the musculature are located chiefly under the epi- and endocardium close to the interstitial connective and fatty tissues. Frequently, the spots show a delicate tracery, the so-called "fat etching," which is especially visible on the trabeculae and papillary muscles in the form of zig-zag lines (lightning figures), arranged transversely to the direction of the fibres.

According to Ribbert, the areas of fatty degeneration correspond to the venous circulatory areas where impaired nutrition or oxygenation prevented complete oxidation of fat in the cells (for contrary opinion, see Borchert).

In high degrees of fatty degeneration, the muscle becomes flabby, fragile, cloudy gray to pale yellow, all depending on the degree of associated anemia. Often the cavities are distended and the walls thinned. If there is brown atrophy as well, a fawn color results. In the child's heart, the change in consistency is usually not so marked.

Fatty degeneration is exceedingly frequent in many different conditions. Quantitative and qualitative blood changes with diminution of the oxygen supply seem to especially favor its development.

For this reason we see it most marked in pernicious anemia, in faulty blood formation and sometimes also in leukemia.

We see fatty degeneration in infectious diseases, especially diphtheria, sepsis, scarlet fever; in bacterial toxemias, in high fever of long duration, in poisoning by phosphorus, arsenic, chloroform, (but only slight, according to Bock), iodoform, ether, alcohol (in the latter it may cause sudden

death especially among dram drinkers. Richter); poisonous fungi (M. B. Schmidt, Herzog); after severe loss of blood; from local disturbances of the nutrition in coronary artery disease. (narrowing, occlusion); following increasing pressure of pericardial exudates, etc. We also see it in more than one-half of all cases as the finale of hypertrophy in valvular lesions, (see also p. 75); in chronic renal affections, emphysema, kyphoscoliosis, etc. Fatty degeneration seems to be a proof of the inability of the heart muscle to continue its compensatory work (secondary fatty degeneration). In valvular lesions a single papillary muscle, usually on the left side, is especially diseased.

In the newborn, fatty degeneration occurs in Winkel's disease which chooses by preference sturdy infants who perish in the first few days with the symptoms of cyanosis, hemoglobinuria, icterus and collapse. At the autopsy are found fatty degeneration of the heart and liver and multiple ecchymoses in almost all the organs. Similar autopsy findings are seen in Buhl's disease in which cyanosis is the chief symptom. In the latter there is a septic infection starting from the umbilicus, or from the bowel (Lucksch), (see Rothler). In Winkel's disease an infection is also probably the cause (*b. coli*). The umbilical vein is spared. In both conditions, melaena, (symptomatic, see under stomach), may be present (see Nurnberger).

Slight degrees of fatty degeneration are very frequent and usually proved only by the microscope (Eyselein). Functional disturbances do not necessarily result; it has even been considered physiological, depending on nutrition (Wegelin, Hotzen), but higher degrees are incompatible with undisturbed function. In any case in which the cardiac muscle shows plain evidence of fatty degeneration, it is diseased, not in the former sense of a metamorphosis of muscle protoplasm into fat, (fat-metamorphosis, Virchow), but as illustrated in animal experiments (see Leick and Winkler), in which the fat entered from one of the fat deposits; but we must remember that fat can enter a muscle fibre only when its protoplasm permits retention consequent to local disturbance of its metabolism ("degenerative fat infiltration," Herxheimer). On the other hand, Borcher is of the opinion that many cases of fatty degeneration of the heart muscle, are "fat phanerosis," *i.e.*, on destruction of the protoplasm, the invisible lipoids distributed in the normal muscle become visible. The fat content (etheral extract), of the dry muscle substance may be increased to 26% in phosphorus poisoning; the normal fat content is 11% (Krehl, see Orgler also). Chemical analysis and microchemical staining do not correspond, because the latter fails with fat-protein combinations. We may speak of fatty degeneration to express the pathological fat content of the heart muscle, but as mentioned under pericardium, it is essential to

differentiate carefully between fatty degeneration and adiposis of the heart (fatty heart) which is frequently, although not regularly, a symptom of polisarca, obesity. The heart is often enlarged, (3 times and more), in obese individuals who have muscular strength and abundant circulation, but in weak obese individuals, the heart is usually small. It must be remembered also in the opposite condition, *i.e.*, in atrophy of the heart subsequent to cachexia, that there is sometimes considerable secondary fat proliferation. Fatty tissue, formed by metamorphosis of connective tissue covers the heart, especially its right side. It is lipoma-like, lobulated, overlaps the right rim and the apex, may be from 0.5 to 1.5 cm. in thickness, forces its way between the muscle bundles and fibres, especially those of the right ventricle, and in very advanced stages, is visible through the endocardium, as lipoma-like clumps, spots, or tiny, long, flat, yellow striae and ridges.

But the latter sometimes appear isolated without invasion, and in individuals who do not suffer from lipomatosis (Thorel), a statement which can be substantiated by the author. Fatty heart and fatty liver occur frequently in hard drinkers as well as in chronic gastritis and chronic leptomeningitis (see Fahr). Cardiac function may finally suffer from the fatty overgrowth and infiltration, because in a small heart the constant pressure of fat on the separated muscle bundles and the tax from the added weight, must eventually lead to atrophy and insufficiency. But the large fatty heart may remain capable of functioning for a long time because its muscle is stronger and is able to hypertrophy. When it does fail, we find either no change at all, or simply sclerosis of the coronary arteries (see Hirsch, *lit.*).

Every experienced pathologist knows that cardiac adiposis causes sudden death following some exertion which taxes the heart, such as running, abdominal compression, overloading of the stomach, chloroform anesthesia, etc. If the fat infiltrated myocardium also shows brown atrophy or fatty degeneration, the wall becomes so seriously weakened and fragile that fatal rupture occurs when sudden strain is put on it or even without strain; it has occurred during sleep. The rupture is usually irregular and ragged as it would necessarily be in this complicated interlaced fibre system.

The clinician calls the fatty degenerated as well as the fat infiltrated and fat covered heart, simply "fatty heart" (Leyden).

#### CALCIFICATION

Calcification of cardiac muscle fibres is rare; it means "calcium metastasis," (case Roth), in which other organs also show calcium infiltrations (stomach, kidneys, spleen, liver) or degenerative processes combined with

calcification (Hedinger, lit.); chronic nephritis is often present and the general calcium metabolism is disturbed (Hart, M. B. Schmidt). Wiechert (lit.) in his case, assumes there is a toxic necrosis, as in paratyphoid infection, which precedes calcification (see also Tilp, B. Fischer). Hart (lit.), too, is of the opinion that calcification takes place in dead tissue only, and that necrosis is caused in a general sense by infections and toxemias. According to Stumpf, lime may be deposited in a fatty heart (see Siebenmann and lit. by Thorel, Krayn). [For discussion, treatment of certain cases and X-ray recommendation see Cutler, E. C. and Merrill, C. Sosman; *Am. J. Roent.*, 12, 312, 1924.—*Translator.*]

**Amyloid** degeneration plays a minor role. It may involve the intermuscular connective tissue and the vessels; and it may coat the muscle fibres, or penetrate between them with a resulting muscular atrophy (Beneke). It may also affect the epi- and pericardium (see p. 23). Calcification may be combined (Schilder, Hecht; lit. Beneke; see also lit. p. 23).

#### CHANGES IN THE MYOCARDIUM CAUSED BY CIRCULATORY DISTURBANCES

**General Anemia.**—Death from exsanguination is death from acute general anemia. The previously healthy heart muscle is pale, grayish red or grayish yellow. The firm consistency of the acute exsanguinated heart differentiates it from fatty degeneration. In the chronic anemias, with oligemia of the heart, *e.g.*, in chlorosis, there is always more or less extensive fatty degeneration and the organ appears light yellow or clay colored. It is seen in highest degree in pernicious anemia (Biermer).

Changes in the coronary arteries cause local anemia of larger or smaller areas.

The coronary arteries. The right and left spring from the root of the aorta and pass forward beneath the auricles one to the right, the other to the left of the large vessels. They form a vascular plexus in the atrioventricular sulcus. The right supplies the right atrium, the right ventricle, with the exception of an anterior strip, the posterior part of the ventricular septum and part of the anterior wall of the right ventricle. Both coronaries supply the posterior papillary muscle of the left ventricle and the anterior large papillary muscle of the right ventricle (Amnomiya). According to Jamin and Merkel, the branches of the right and left anastomose in a variety of ways, and according to Hirsch and Spalteholz, who injected both dog and human hearts, anastomoses are not only present, but are abundant, although with individual variations. These anastomoses include the finest peripheral twigs in the papillary muscles, subendocardial and subpericardial layers; coarser anastomoses of the main stems are present only in a few places and these especially in the left auricle, so that the coronaries are not anatomic end arteries. Nevertheless the

anastomoses are unable to prevent the formation of infarcts after occlusion of the larger distributing branches. More detailed investigations of their functional capacity in man are much needed. But it is certain that with gradual occlusion of a branch of the coronary artery as occurs sometimes in cicatricial syphilitic aortitis, enlargement of the other coronary artery may take place and a slow, gradual, functionally perfect, collateral circulation develops sufficient to supply an immensely hypertrophied heart. In rare cases there is only one coronary artery, and in an observation of the author in a 47 year old woman, it was the left which was present, (see Abrikossoff, Heitzmann, in reference to the rare origin of a coronary artery from the pulmonary artery).

The coronary veins unite in the atrioventricular sulcus into the coronary sinus (*vena magna cordis*) which enters the right auricle (coronary sinus valve—valve of Thebesius). Furthermore, it is said that small veins of the inner myocardial layers open directly into the cavities of the heart (von Langer, Toldt). [For review of coronary arterial disease, see Benson, R. L., *Arch. Path.*, 2, 876, 1926.—*Translator.*]

The changes in the coronary arteries in question are (*a*) acute occlusion by emboli, *e.g.*, thrombotic masses from a leaflet of the aortic valve or a fatty degenerated part of the intima of the aorta. This embolic occlusion is rare compared with the following form: (*b*) occlusion from local changes of the arteries, *viz.*, common arteriosclerosis with thickening, fatty degeneration, atheromatous softening and calcification of the intima and rarely of the media; this often begins early in life (Orliansky) and although not rare in young men in mild degree especially in the left coronary artery, (Monkeberg), it is especially common in more advanced age. (See short dissertation on angina pectoris by H. Cohn.) To these local changes, thrombosis may be added with resulting acute occlusion. The lumina are usually open but become narrower along the course of the vessels. Endarteritis, with increasing thickness of the intima may be present in earlier years as a concomitant of syphilitic aortitis, (see under arteries), and may eventually lead to closure of the entrance, while the artery further along in its course is dilated. Furthermore, an acute focal mesarteritis is not a rare occurrence during the course of infectious-toxic diseases such as scarlet fever, diphtheria, measles, eclampsia, endocarditis, pyemia, etc. (Wiesel, see also Scharpff). The anterior descending branch of the left coronary is most frequently affected.

A vegetative endocarditis may penetrate the coronary artery for some distance. Traumatic thrombosis has been observed, as in a case of Eug. Fraenkel after the twisting of a suture around the artery.

For aneurysm of the coronary arteries, see page 4.

Consequences of vessel occlusion.

(a) Obstruction of both coronary arteries or the obstruction of one in the presence of an existing closure of the other, causes death, either instantaneous, or in a few hours.

(b) When a large branch, or the stem of one coronary artery is acutely occluded, sudden or less rapid death may result, with the symptoms of angina pectoris. These different effects depend on the kind of closure, *i.e.*, whether perfect and instantaneous from an embolus, or one completed by subsequent thrombosis. The condition of the other coronary artery and of the myocardium are other factors. If the other coronary is arteriosclerotic and the myocardium poor with brown atrophy, fatty degenera-

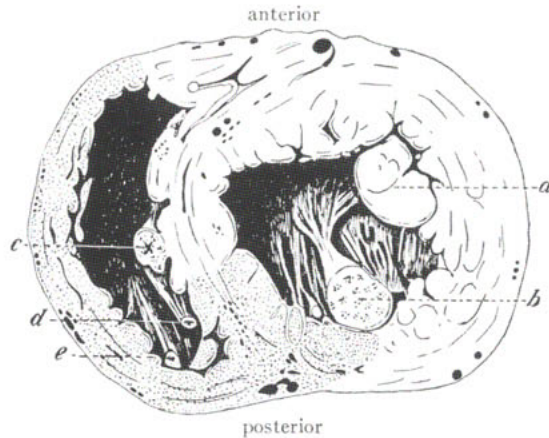


FIG. 20.—Areas supplied by the coronary arteries. Cross section through both chambers, viewed from below. The black dotted area is supplied by the right, the area left, white, by the left coronary artery; a, anterior; b, posterior papillary muscle of the l. ventricle; c, large; d, median; e, lateral papillary muscle of the r. ventricle; b and c are supplied by both coronary arteries; modified from illustr. by Amenomiya (l.c.);  $\frac{2}{10}$  nat. size.

tion, fat or cicatrices, then acute occlusion of the right or left causes sudden death (Oestreich, Barth and lit. by Thorel).

The few observations on man do not permit judgment of the effect of acute closure of a healthy left coronary artery with the right one patulous and a perfect valvular apparatus and myocardium. The author's observation of this kind almost equalled a physiological experiment. A laborer, very sturdy, 35 years old, worked in the morning as usual; at 1:00 P.M. he showed sudden dyspnea, quickly followed by severe pulmonary edema, resulting in death at 7:45 P.M.; autopsy revealed: closure of the left coronary artery by a small, loose, firm, embolus in the anterior descending ramus, from which softer, loose, thrombotic masses extended up to the origin of the circumflex ramus; a flat thrombus the size of a lentil with roughened surface as though torn off, lay close above the posterior leaf of the aortic valve. There was globular distension of the left ventricle

(cardiac paralysis), with the right ventricle in comparison small, firm, valves intact, good musculature (also microscopically); both lungs flooded with edema.

(c) If a small branch is occluded, ischemia of the part supplied is the consequence. At first the consistency remains normal, but its color becomes steadily lighter, until the tissue dies, when it becomes clay colored, gray or yellowish and usually firmer and drier than its vicinity (coagulation necrosis). This is the familiar anemic necrosis, or anemic infarct. These necrotic areas may show map-like figures of varying shapes caused by the distribution of the vessel.



FIG. 21.—Infarction and perforation of the wall of the left ventricle with vegetative mitral endocarditis. L. H. '89.

Microscopically, at first, the outlines of the fibres are still preserved and the cross striation intact, but with the exception of parts of the connective tissue, there is no nuclear staining. Then follow degeneration of the necrotic muscle fibres, with waxy or hyalin vacuoles, and lumpy or granular disintegration. In some places, the muscle fibres show fatty degeneration. In the interstices between the necrotic muscle fibres are found fresh foci (a few days old) of fat-containing leucocytes. Some muscle fibres are much swollen.

At the periphery of the foci, is the red line of hyperemia. Blood extravasation occurs from the neighboring vessels (hemorrhage). If the necro-

tic area itself becomes saturated with blood as in smaller foci, it constitutes the dark red hemorrhagic infarct, which later becomes brown or rusty in color. Often, a small, angular, yellow seam of fatty degeneration is present between the red edge and the clay colored focus, *i.e.*, in the peripheral parts of the anemic area, since at least some blood percolates into this region from the hyperemic surroundings; when the anemia is complete, the inevitable result is necrosis.

What becomes of anemic infarcts? First they soften secondarily and become friable from serous saturation from the neighboring vessels (soften-

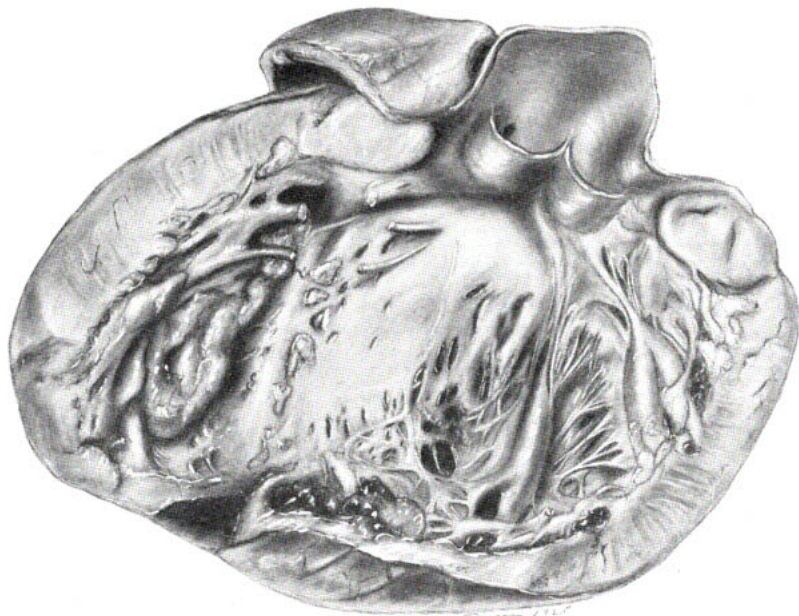


FIG. 22.—Infarction of the heart muscle. Thrombosis of the anterior coronary artery. The infarction present toward the apex of the left ventricle covered by thrombus. Such lesions heal occasionally but later form a so-called cardiac aneurysm from the stretching of tissue less resistant than the original muscle. L. H. '16.

ing of the heart, or better, myomalacia). Rupture at this time is relatively rare, but perhaps there is a small, irregular tear, the edges of friable myocardium penetrated with blood. The epicardium is bulged outward by bluish red, translucent, blebs of blood.

But when the soft area bulges as a whole (acute cardiac aneurysm) rupture is quite common.

An acute dissecting cardiac aneurysm is developed when only the inner subendocardial layers of muscle are torn; the blood penetrating the myocardium separates the muscle layers, perhaps for a considerable

distance. The cardiac surface then bulges outward like a hemisphere. Perforation may occur at the apex of this prominence, but when there is extensive dissection, tears occur at the cardiac base.

Organization of the infarct is much more frequent, however. Vascular granulation tissue from the reacting interstitial tissue of the neighborhood penetrates the necrotic area as the disintegrated material is removed by cells and absorption (see p. 9). The end result, when the change to firm, satiny, fibrous connective tissue is completed, is a scar (myocardial cicatrix). While it is forming, the process should be called fibrous myocarditis, or, better "fibroplastic myocarditis" (see fig. 26). The areas which are to become connective tissue first appear grayish red and slightly sunken, later they shrink more and more into a non-vascular, white, firm cicatrix with brownish spots. Microscopically, the yellowish brown granules are contained within connective tissue cells which are rich in protoplasm and varied in shape (phagocytes). The pigment owes its origin chiefly to blood coloring matter from the hemorrhage; it gives the iron reaction, but may be derived in part from the pigment of destroyed muscle fibres, in which case it is darker brown and gives no iron reaction. In the vicinity of the scars are fat deposits, hypertrophic muscle fibres, fibres with remarkably large nuclei rich in chromatin, sometimes also muscle giant cells (attempts at regeneration?). The scars contain abundant elastic fibres, (see Faber and others).

If the scars are numerous, the heart muscle, on section through the ventricular wall, appears spotted or striped, tiger-like, color flecked; if old it is spotted white and brown; if more recent, it is grayish red; fresh changes are clay colored with an outside yellow zone of fat infiltration and a hyperemic edge alternating in the same specimen with typical hemorrhagic infarction.

Should many scattered small necroses occur which undergo cicatrization, we have a "disseminated fibrous myocarditis." Hardening of the heart muscle (myocardial cirrhosis) and hypertrophy are frequently combined, doubtless for purposes of compensation. This is often seen in large senile hearts.

Scars are much more frequent on the left side (left coronary artery) than on the right (see heart cicatrices and consequences on p. 68).

### **Myocarditis. Inflammation of the Heart Muscle**

According to the part chiefly affected, we may consider a parenchymatous or muscle type, and an interstitial or connective tissue type, the latter either acute or chronic in nature. But it is clear that the muscle fibres must always be changed in interstitial myocarditis, and conversely, in parenchymatous degenerative inflammation there is always change in

the interstitial tissue. For this reason it is well to speak of a predominantly parenchymatous and a predominantly interstitial myocarditis.

#### PARENCHYMATOUS MYOCARDITIS, PREDOMINANTLY DEGENERATIVE MYOCARDITIS

This type develops acutely, and appears as cloudy swelling, which either regresses or becomes fatty degeneration. The interstitial tissue is involved in varying, but usually mild, degree, and shows a small round cell infiltration. It is merely hair-splitting to argue over "parenchymatous myocarditis" or "myocarditis with marked predominating parenchymatous involvement" (Ribbert). There are still other forms of acute parenchymatous degeneration, such as "vacuolated or hydropic degeneration" in which droplets form in the cell protoplasm; hyalin degeneration; granular lumpy disintegration; loss of cross striations, with glassy and hyalin droplet appearance analogous to waxy degeneration (see under muscles), such as von Flessinger and Roudowska observed, especially in preagonal cardiac arrhythmia of the atrioventricular bundle. In anemic necrosis (p. 58), there are reactive growth of connective tissue and gradual absorption of dead masses to fill out defects in the loose scar tissue. Fatty degeneration frequently combines with the forms of degeneration just mentioned, especially in pharyngeal diphtheria, protracted scarlet fever (see Stegemann), typhoid fever, in which the heart is often remarkably flabby, pneumonia, (see Liebmann) in which the right ventricle is only exceptionally affected (Fulci). The fat is focal or diffuse, and appears not only during the height of these diseases, but also during convalescence; it may cause severe enough cardiac disturbances to cause death from cardiac paralysis. As causative factors we should consider the blood changes present in infectious diseases and fevers, *i.e.*, diminished oxygen, the entrance of bacterial toxins, etc. The muscle may become so fragile that it is properly called inflammatory softening, but in children's hearts the changes in consistency are usually not so marked. As long as the cloudy swelling is present, the heart muscle is somewhat fragile, and usually cloudy grayish red, but with increasing hyalin degeneration it becomes paler and grayish or whitish yellow as though cooked.

Enlargement of the cavities is frequent, especially of the left (see Sorensen), but thrombus formation as well as embolism is rare (Deguy and Weil, *lit. by de la Chapelle*).

In diphtheria, the myocardial findings are inconstant and varied, probably because of qualitative differences in the diphtheria toxins (Fahr); they also vary according to earlier or later stages under investigation, but the severity of the infection does not necessarily correspond to the histological changes (Huebschman, *lit.*). While Birch-Hirschfeld, Leyden,

Romberg and others consider an interstitial infiltration as primary, although it is not to be seen before the 9th to the 15th day of the disease (Hallwach and Tanaka), others consider the predominant factor to be parenchymatous, *i.e.*, fatty degeneration, the frequency of which is recognized by all (see Hotzen, Rosenbach, Schemm, and especially Ribbert). Waxy degeneration is also found, and Tanaka emphasizes parenchymatous lumpy disintegration. Eppinger (toxic myolysis), Moenckeberg, Fahr (myolysis), and others, and recently Huebschmann, have reported primary parenchymatous lesions. From all this we may assume that diphtheria toxin injures first and chiefly the muscle fibres, which show either a finely sprayed fatty degeneration of comparatively slight importance as long as nuclei and cross striation persist (Monckeberg), or more severe

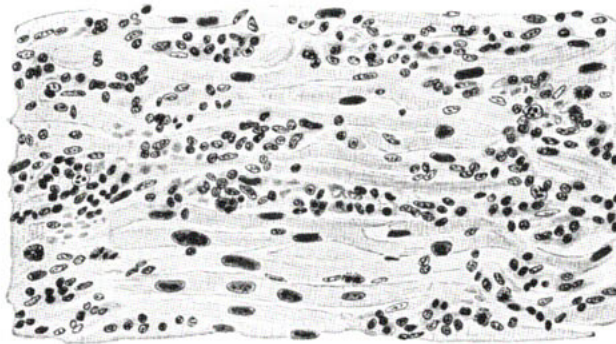


FIG. 23.—Acute myocarditis in pharyngeal diphtheria showing gaps of disintegrating muscle fibers with well preserved fibers containing large dark nuclei; the former invaded by lymphocytes, leucocytes, isolated eosinophiles and fibroblasts with pale elongated nuclei; from a child, cardiac death;  $\times 300$ .

swelling and lumpy disintegration. These changes appear alone or in combination. Secondly, there is usually a round cell infiltration which may be quite marked (see above). Plasma cells, and sometimes eosinophilic cells, also make their appearance (Tanaka Wulffius). In severer cases, the destruction of muscle stimulates granulation (fig. 23), with the final result expressed in a fine, loose connective tissue (see Anitschkow also). Very rarely, microscopic dense scars are found, (Huebschmann). The muscle has a tendency to acute dilatation on account of numerous foci of loose connective tissue. These, and the other fresh myocardial changes are sufficient to explain the acute "cardiac death" so frequent in diphtheria. Indeed the heart, especially the left, is often dilated with but slight anatomical changes. Both thrombosis and embolism are relatively rare. The transmission system may remain free of changes, or may also be involved (Tanaka, Rohmer, Heilhecker).

Heller first described regenerative processes in the diphtheria heart consisting of enlargement and better staining of nuclei, segmentation of nuclei, hypertrophy of fibres and multiplication by lateral division of myogenous cells and muscle bands. These findings were verified by others (Frenzel, Huebschmann, compare, with the *per contra*, Anitschkow).

#### PREDOMINANTLY INTERSTITIAL MYOCARDITIS

##### (a) ACUTE INTERSTITIAL MYOCARDITIS (FIG. 25)

A sharply localized, and a more or less diffuse form may be differentiated. The former develops by continuity from an ulcerative endocarditis, thus forming a heart ulcer (comp. fig. 9) or by the extension of a suppurative pericarditis into the myocardium, or, much more frequently, from infectious emboli in ulcerative endocarditis, pyemia, etc. The organisms are usually staphylococci, especially from osteomyelitis, but streptococci, sometimes pneumococci, rarely gonococci (Councilman) all may reach the heart muscle through the blood from the coronary arteries. A suppurative inflammation is the usual result.

Cloudy speckled foci develop wherever bacteria lodge which is often in the vessels. These foci show cloudy swelling and necrosis, and further out, there is fatty degeneration, changes which can be considered as progressive death of tissue due to diffusing bacterial toxins. The necrotic masses are usually surrounded by a reactive zone of leucocytes (fig. 25). When pus cells enter a necrotic focus, an abscess is formed.

Although this course of events is the more frequent, the process does not necessarily develop into a suppurative myocarditis. The bacteria or their toxins may cause only necrosis with peripheral leucocytic infiltration, for the virulence of the bacteria may be diminished. This is often seen in pneumococcic endocarditis. Tiny scars may form from reparative connective tissue proliferation. There are also cases in which purulent liquefaction does not occur, but cellular infiltrates of proliferating fixed connective tissue cells, lympho- and leucocytes, eosinophiles, etc., gather without causing marked changes in the muscle fibres; this constitutes the true interstitial foci. In other cases, it is very difficult to decide if the involvement of the muscle fibres is primary or secondary. (hyalin degeneration, necrosis). The productive inflammation is very marked in some foci, and we see polymorphous fibroblasts and much connective tissue.

Aschoff first described a type of myocarditis, frequently, although not always, accompanying articular rheumatism (polyarthrits rheumatica). In this type are found inconstant, nodular, perivascular foci within the interstitial tissue, usually recognizable only microscopically, but occasion-

ally, macroscopically (Sternberg). They are called Aschoff's nodules, and are composed of peculiar, large giant cells with large nuclei of connective tissue origin, which are grouped in a radiating or fan-like form intermixed chiefly with lymphocytes, but also with eosinophiles and plasma cells. The centers of these nodules become necrotic and later are partially or completely fibrosed. According to the opinion of many authors, (Thorel), this rheumatic myocarditis, (Eugene Fraenkel, lit.) is a specific disease of the heart muscle. The nodules which select by preference the richly vascular subendocardial layers may threaten destruction to the numerous branches of the conduction system. The importance of diplo-streptococci which were cultivated from the heart blood of cases



FIG. 24.

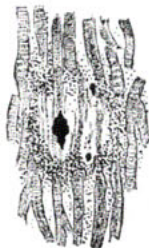


FIG. 25.



FIG. 26.

FIG. 24.—Anemic necrosis of a small portion of muscle fibers; slight infiltration of leucocytes into the interstitial tissue; (low power).

FIG. 25.—Small cardiac abscess; in the center, long black masses of bacteria surrounded by a light necrotic zone and beyond this a wall of leucocytes; puerperal pyemia; Gram stain (low power).

FIG. 26.—Scar in the myocardium due to sclerosis of coronary artery; four vessels lie in the fibrous tissue; the upper three, with thickened intima are arteries. The fibrous tissue is lost between the adjoining muscle fibers (low power).

of rheumatic polyarthritis in some instances, and which, in animal experiments, caused necrotic inflammatory foci with a tendency to form scar tissue, is still doubtful (Eug. Fraenkel), especially in view of the experiments of de Vecchi (lit.), who succeeded in developing perivascular myocardial foci with sterile blood from patients with acute articular rheumatism. Their resemblance to Aschoff's nodules were pointed out by the author. In both articular rheumatism (rheumatism nodosa), and in chorea minor, which is related to the former, the presence of subcutaneous nodules to the size of hazel nuts (rheumatic nodules) has been known for a long time. They are found not only in the vicinity of the swollen joints, but also in other places visible to the eye, and are analogous to those in

the myocardium (see Fahr). Similar small macroscopic nodules have been found on the galea aponeurotica (Tilp. Jacki. lit.).

Interstitial inflammatory foci in the myocardium are also found frequently in other endocardial and valvular lesions.

In pharyngeal diphtheria, microscopic interstitial inflammatory foci are often found in large numbers (see p. 61), and occasionally also in other infections. Staubli speaks of eosinophilic myocarditis in rabbits with the trichina heart (compare in man, Hubner, Knorr and Simmonds "myocarditis trichinosa"). Diffuse interstitial inflammation with the formation of fluid exudate and cellular infiltration is rare in infectious diseases, but is occasionally seen in scarlet fever and in pharyngeal diphtheria; extensive pale yellow foci may also be present.

Isolated, acute or subacute diffuse interstitial myocarditis is rare; when it occurs, there are large glassy yellowish to grayish white foci in the myocardium. The author saw two cases which looked like leukemic infiltration; there were washed-out figures in the myocardium, which extended so far that little normal musculature was left. The heart is usually dilated and considerably enlarged; sudden death frequently ends the condition. Other organs show few abnormalities; the clinical course is peculiar (Pal); it prefers younger individuals. The etiology varies. In a case of the author, there was an infected, but rapidly healing, burn; in another case, pus developed in the incision after operative removal of a tuberculous cervical lymph node. In Wolf's case, there was an unimportant lesion of the elbow; in Aschoff's case, one of the hand; a facial carbuncle which healed after incision was present in a case of Sellentin (lit.). In a case of Zuppinger, a child had a phlegmon of the foot; trauma and other obscure causes have also been recorded (lit. in appendix). Probably the toxic action of bacterial products is concerned, for bacteria themselves were never found in the foci. Histologically, the findings are not uniform; in some, the mildness of the parenchymatous changes is emphasized (for instance, the cases of Sellentin, of Aschoff); while in others we find more marked fatty degeneration, and disintegration to complete atrophy of muscle fibres. There are undoubted attempts at regeneration with proliferation of free muscle nuclei (see Wolf) and myogenous "wandering cells" (see Saltykow). There are muscle giant cells, epithelioid cells, leucocytes and lymphocytes, eosinophiles, and other cells. The inconsistency of the parenchymatous changes points to the interstitial changes as the essential, although L. Cohn considers hyalin degeneration the primary lesion.

Abscesses sometimes appear in enormous numbers as globular or elongated striae and foci. A hyperemic or hemorrhagic halo surrounds

small military abscesses which may often be picked out with the point of a knife.

The areas of predilection, as for all focal myocarditis, are, according to Koster, in the papillary muscles, especially the left, where there are small striae, or more rarely, globular knobs on their apices, in the lower two-thirds of the surface of the left heart, and on its posterior surface more toward the middle. The anterior right papillary muscle is next preferred. Other favorite places are the subepicardial muscle layers, and for this reason, Koster, advises slicing fine sections parallel to the surface to find them more readily. Their size is usually small, but occasionally foci as large as a pea develop by confluence, rarely, larger ones are found. If the infectious emboli are larger, inflammatory and simple mechanical sequellae are combined and anemic infarcts border on abscesses, so that the former finally suppurate. Abscesses have been known to heal, as the bacteria die and the pus cells disintegrate and are absorbed. Granulation tissue invades and covers the focus which changes to a fibrous scar (myocardial scar). The necrotic foci may be dealt with in the same way. In other cases, the abscess becomes encapsulated. Calcification of the thickened pus is rare.

The consequences directly due to the abscesses vary according to their location and size: (a) If the focus lies under the epicardium, there is danger of pericarditis (purulent, fibrino-purulent); (b) if located in a papillary muscle, separation and acute insufficiency of the valve may occur; (c) if directly under the endocardium, it may break through and release emboli, especially into the spleen and kidneys, or it may produce ulcerative myocarditis. If blood tunnels into the ulcer, it distends in a short time and forms an acute ulcerative cardiac aneurysm which may progress to fatal rupture. On p. 32, was described another form of cardiac ulcer from extension of an ulcerative valvular endocarditis to the cardiac wall; from these also, acute cardiac aneurysms develop; (d) if the abscess, *i.e.*, ulcer, is located in the ventricular septum, (usually in the upper part), a communication between the ventricles may develop; (e) in other cases, the ulcer bulges toward the right auricle or the pulmonary artery. Rupture or thrombus formation outside of the aneurysm sometimes occurs and may cause pulmonary embolism.

Ulcerative cardiac aneurysms may become chronic, in which case the wall contains a scar.

#### CHRONIC FIBROPLASTIC INTERSTITIAL MYOCARDITIS; FORMATION OF SCAR TISSUE

We must differentiate (1) the rare, independent, chronic productive myocarditis; (2) the very frequent secondary productive myocarditis

which follows an acute process—usually a myocardial necrosis and at times aseptic cardiac wounds (lit. by Cevidalli and see lit. p. 83), as a reactive reparatory attempt. In both cases, scar tissue may form (cicatrix, see circumscribed fibrosis of the myocardium).

If the process has not completely ended, which cannot be decided as a rule macroscopically, we are justified in speaking of fibrous myocarditis, or, better, "fibroplastic" myocarditis.

This formation of scar tissue ends in the development of calloused connective tissue, rich in elastic fibres which evolves by a modification of granulation tissue and becomes established within the cardiac wall in



FIG. 27.—Myocardial cicatrices; cross section through the anterior end of the ventricular septum; the white streak is the epicardium; natural size.



FIG. 28.—Fibrosis of the tip of a papillary muscle.

place of, and at the expense of, the musculature. These changes are best recognized by flat sections through the heart walls. At first, there is a red, somewhat soft, depressible focus in the musculature; after cicatricial transformation, this is grayish red or pale brownish to white, resembling asbestos, tendinous and shiny; it sounds gritty under the knife, and is depressed below the section surface. The foci usually are flat, but are sometimes nodular (fig. 27).

An independent, insidious, chronic productive myocarditis has been described following articular rheumatism, typhoid fever, puerperal fever, and has also been accepted by many clinicians in relation to other infections, such as measles and pneumonia, especially in children (lit. by Thorel; see below as to syphilis). It is probable also that an acute myocarditis

may run a protracted course, and in this way, it is possible to have an occasional chronic myocarditis in those infectious diseases in which we more frequently find acute myocarditis.

There are other processes in which a productive myocarditis is a secondary complication as in: (a) Acute myocarditis, especially an abscess, but, in any given case, it may be merely acute parenchymatous degeneration (see p. 61). (b) Scar tissue in the outer myocardial layers may follow a chronic pericarditis. (c) A parietal endomyocarditis following valvular diseases. A conus stenosis can thus be developed in the right heart, rarely in the left, followed by true stenosis with subsequent dilatation and hypertrophy. Often the papillary muscles, especially the left, or separate trabeculae become fibrosed (fibrous myocarditis or papillary fibrosis) for which mechanical factors are sometimes responsible (pulling). Valvular insufficiency may result. (d) Necrosis of the myocardium is most frequently caused by changes in the coronary vessels, (arterio-sclerosis, endarteritis, thrombosis, embolism). These changes in the intima are not found in the larger vessels alone, but, quite frequently indeed, in the small intermuscular branches of the coronaries, as well as in the arching twigs which enter the large papillary muscles (see p. 55). The most common causes of these conditions are arterio-sclerosis and syphilis. The most minute, and the largest cardiac scars are met in this connection. Sometimes there is a syphilitic mes- or end-aortitis, and sometimes there are true gummata in the pericardial adhesions. This was seen by the author in a man 35 years old, in whom the generally dilated and hypertrophic heart showed such a high degree of scar tissue formation that the wall (also that of the right ventricle), was occupied by scars the size of a dollar; the beginning of the aorta was much distended and there was advanced arterio-sclerosis. (e) Not all cases of fibrous myocarditis in syphilitics can be charged to vascular changes; there are some in which toxic action on the muscle fibres themselves must be considered as the primary cause. The destruction of muscle fibres is followed by reparatory connective tissue overgrowth. On the other hand, there is a primary chronic interstitial myocarditis in syphilis, with or without the formation of gummata, (cases of Buschke and Fischer in congenital lues, but only the latter case is characteristic; in a third case, scar tissue formation with aneurysm followed the disappearance of gummata after specific treatment). Experimental chronic myocarditis was studied by Fleisher and L. Loeb, (lit.).

**Consequences of Cardiac Scars.**—If the scar surrounds the conus pulmonalis or the aorta like a ring, it leads to stenosis of these parts, but this is an infrequent occurrence. On the other hand, an area with a large scar may be bulged outward by the blood pressure and thus form a

chronic cardiac aneurysm; (*aneurysma cordis partiale*, Rokitansky). This must not be taken too literally; most of such aneurysms are not especially easy to recognize but become noticeable only on section of the heart. Nevertheless cases do occur in which a large spherical bulging the size of a fist and larger can be seen (transverse bag-heart). The aneurysmal wall, when large, consists only of scar tissue, sometimes calcified. On the outside, there is usually a calloused thickening of the epicardium, and not infrequently, bands or flat adhesions join both pericardial surfaces.

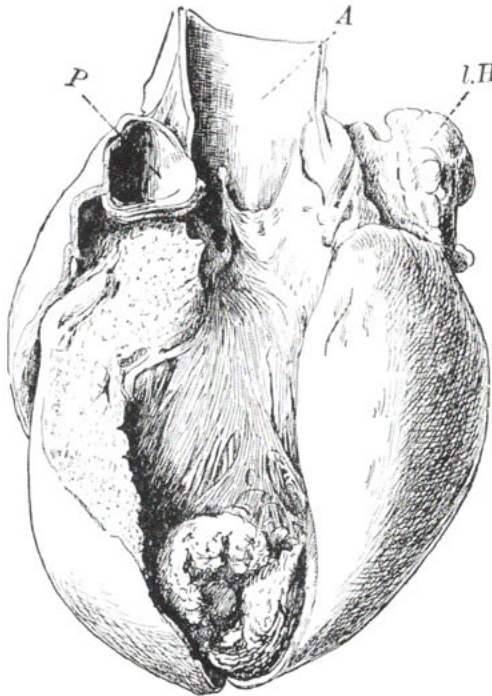


FIG. 29.—Typical chronic cardiac aneurysm anterior, at tip of left ventricle; the wall cicatricial, calcified and thinned; in the aneurysm a parietal thrombus with central softening; A, aorta; P, pulmon. art.; L.H., left auricle.

Frequently, massive thrombi with ribbed layers collect within the aneurysm (these are also called parietal thrombi since they are attached to the wall), and these sometimes soften in their interiors, or they desiccate and become of horny hardness (fig. 29). Embolism is frequent (fig. 30), and organization is rare.

Rupture of a partial cardiectasia is relatively rare, because cicatricial thickening of the endocardium and frequently of the pericardium protects; laminated parietal thrombi also protect. Nevertheless, in any group of spontaneous cardiac ruptures (see p. 4), those due to aneurysm are quite

frequent. The favorite location of aneurysms is in the anterior wall of the left ventricle, near the apex (anterior descending branch of the left coronary artery, which also is the sole supply to the anterior large papillary muscle of the left ventricle). It occurs chiefly in old men (Strauch).

The chronic aneurysms which develop by scar formation in the septum bulge to the right; other localizations are rare.

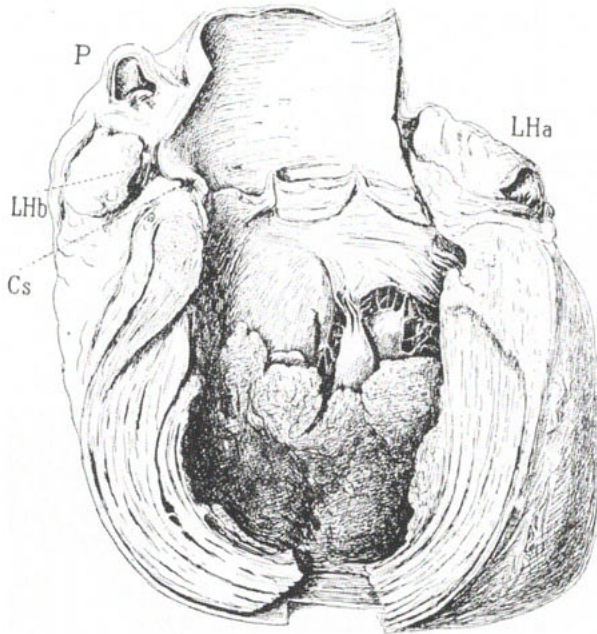


FIG. 30.—Cardiac aneurysm filled with immense thrombus partly laminated, horny and firm; the rest of the wall of the left ventricle adjacent to the aneurysm cicatricial and thin; partial adhesions of the pericardium. The opened left ventricle is shown. LHa, left auricle, cut; a portion to the right of the cut (LHb); Cs, left coronary artery, P, pulmonary artery. Sclerosis of the coronaries; weight of heart 910 gms. Man 60 years old with chronic nephritis (large white kidney) died of uremia. Embolic gangrene of both feet;  $\frac{1}{2}$  nat. size.

#### APPENDIX. FRAGMENTATION AND SEGMENTATION OF THE MYOCARDIUM

This is probably an agonal change which develops under the most varied conditions; it can be recognized with certainty only by the microscope. In a general way, it consists of transverse separation and splitting of the cardiac muscle fibres into small fragments, causing them to appear chopped up, or torn jaggedly. Sometimes the edges of the transverse tears show longitudinal splintering or unraveling (primitive fibrillae!). The tears and separation occur not only within the cross stria (p. 48), but anywhere along the continuity of the fibres, (true fragmentation); fracture lines through nuclei are rare.

According to Jordan and Bardin, segmentation and fragmentation are but different degrees of the same process.

This change is found most frequently in the left ventricle, especially marked in the papillary muscles and inner layers. It is rarely general in distribution.

These findings have often been made in sudden death (hanging, asphyxia, drowning, execution, etc.), in which the heart muscle was perfectly healthy. On the other hand, it is found in the most diverse diseases, where perhaps septic processes are prominent. We must assume, (*a*) when the muscle was healthy, that the short agony during sudden death suffices to fracture the heart mechanically by violent spasmodic contractions, while (*b*) nutritive disturbances of various kinds (among them senile atrophy, see Wideroe), may diminish the firmness of the muscle sufficiently to permit the last, more or less spasmodic, contractions, which need not be especially violent, to cause fragmentation. The change therefore cannot be considered of diagnostic importance, *e.g.*, in the causes of death, from a suddenly acting force. Its frequency increases with progressive age. It is absent in the newborn. The fragmented heart muscle may also show fatty degeneration.

Giese's statements, that it is experimentally possible to produce typical fragmentation by putrefaction, which would mean that fragmentation is actually a cadaveric condition, were not substantiated by Stamer (*lit.*), nor can he subscribe to the opinions of Tawara and Aschoff that mechanical post mortem procedures cause full development of fragmentation which was but begun during agony; indeed, like the author, he supports the opinion of Recklinghausen of the agonal cause of these changes (see also Lissauer, experiments, *lit.*). The dissolution of cardiac muscle fibres, occasionally observed in putrefaction, is distinct from fragmentation and segmentation.

The designation "myocardite parenchymateuse segmentaire" (Renaut), is poorly chosen, since the process has nothing to do with inflammation.

### Changes in the Size of the Heart

The normal heart is approximately the size of its owner's fist (Laennec); the average weight in women is about 250 gms., in men, about 300 gms. (See more details about its weight at different ages by Thoma, W. Muller, exact methods of weighing, and the data and charts of Vierordt, also Wideroe for mass conditions of the heart in pathologic cases; and Kirch in reference to the laws of alteration of internal size of the normal and pathological heart.) While there is no noteworthy difference in the thickness of the ventricles of the heart of the fetus, in adults (according to Krause),

the right ventricle is 0.5 to 0.7 cm., the left 1.1 to 1.4 cm. These measurements, however, vary within rather wide margins, as do the weights and measurements of the hearts, *e.g.*, of soldiers (see Fahr). In hypertrophy, the left ventricle may be 3 cm. thick in the vicinity of the mitral valve. When giving measurements, it is necessary to state where they were taken, and the trabecular substance, and pericardial fat must be deducted.

Post mortem rigor of the heart which causes contraction (pointing and hardening) must also be taken into consideration when judging the thickness of walls and the size of cavities. It appears early, even in one to two hours, (Strassmann, Fuchs, Volkhardt, Aschoff), and complicates the problem of deciding in which phase of heart action death occurred. It may, however, be considered as settled that the heart always dies in diastole (animal experiments, see Rothberger, Eckstein). Usually the left heart at autopsy is almost completely empty (systole). while the right heart is filled, (half diastole, midway between diastole and systole); if the rigor subsides, and the blood in the left auricle remains fluid the left ventricle may fill by suction. As a whole, the heart then becomes wider, flabby and compressible. As a rule, the right ventricle and auricle in the cadaver contain much blood, which is forced in death from the contracting arteries into the veins. This condition neither excludes death from cardiac paralysis, nor does it prove death from asphyxia. Generally speaking, in death from cardiac paralysis we expect distension and globular enlargement of the left ventricle (comp. observation on p. 57), while in death from asphyxia, *e.g.*, in embolic occlusion of the trunk of the pulmonary artery, the right ventricle is filled to the maximum. In severe parenchymatous degeneration of the muscle, as in sepsis, chloroform poisoning, (also in poisoning by phosgene gas, see W. Koch), the rigor may not develop or may quickly resolve in decomposition. Decomposition and adsorption, (see p. 51), may cause fluid blood to disappear from the heart cavities.

**Decrease in Size.**—When congenital, it is called cardiac hypoplasia. More marked degrees are rare. Slighter degrees are seen in combination with poor arterial development (hypoplasia), narrow aortic system and chlorosis, (Virchow). It is still a question which is cause and which is effect.

Another much debated question is whether the narrowness of the aortic system is primary. Suter denies it, while Scheel admits it, in the sense that a relatively narrow aorta is present in the years of puberty, because the growth of its lumen does not keep pace with general development. Strasburger proposes calling general aortic narrowness, incomplete dilating power of the aorta. The author supports the theory of a congenital narrow aorta with thin walls but increased elasticity often com-

bined with a tendency to fatty degeneration of the intima—an “aorta angusta” in which a small heart is also found. Frequently, the endocardium of the left ventricle is milky, cloudy, and thickened. Aortas are seen of but three to four centimeters in circumference in the pectoral area, and we may assume with Burke, that in youthful individuals, a left cardiac hypertrophy with later dilatation and arterio-sclerosis, especially of peripheral vessels, are the consequences (see Apelt, Strauss, v. Ritook, Viesel, etc., also Kani, Rossle, Herxheimer, Romberg, Kulbs, Westenhofer, Sternberg, lit.). Bartel, and the author also, saw aortic hypoplasia in status lymphaticus (see Stoerk, Bauer, lit.). Others fail to see such relations, (L. Kaufmann, Jaffe, and Sternberg), and believe that the narrowness is misleading, being caused by the greater elasticity of the vessel and its post mortem contraction. Bauer, however, thinks that the narrow aorta is part of the symptoms of constitutional hypoplasia as we find it in status lymphaticus, (see Bartel also).

The width of the aorta of the adult male in the ascending part is 6 to 8 cm., in the pectoral part 4 to 5 cm., abdominal part 3.5 to 4.5 cm. It is less wide in women.

An acquired diminution in size is called atrophy. The muscle fibres themselves become smaller. In general senile atrophy, in phthisis, in the cachexia of carcinoma, etc., the weight of the heart may be reduced to 150 gms. and less, as a consequence of general malnutrition.

Then atrophy is often combined with brown pigmentation. During life, we frequently see in x-ray pictures, a small, elongated cardiac shadow combined with a long small aorta and a low position of the diaphragm (lit. by Kulbs).

In a girl 18 years old with advanced intestinal tuberculosis, we saw a heart weighing only 100 gms. In very old men, we find an atrophic brown heart which always shows connective tissue hyperplasia especially in the auricular myocardium; this belongs to the picture of general senile marasmus. The large senile heart depends, as a rule, on secondary hypertrophy with emphysema, arterio-sclerosis, etc. In sturdy old men, such a heart may function perfectly.

**Increase in Size.**—This is caused by hypertrophy and thickening of the walls, or dilatation of the cavities, or both together. We understand by hypertrophy, an increase in the mass of cardiac muscle caused by increased activity. We differentiate (*a*) simple hypertrophy, thickening of the wall without changes in the cavities, and (*b*) eccentric hypertrophy, also called “hypertrophy with dilatation.”

Concentric hypertrophy, in the sense that the addition of muscle mass narrows the cavity, occurs only rarely in adults (Horvath, see also Kirch); usually such a picture is only the effect of rigor mortis. On the other hand,

the fetal heart does show concentric hypertrophy with thickened walls and small cavities, since it must not only keep up the circulation of its own body but must overcome the resistance of the fluid medium, *i.e.*, the amniotic fluid (Miura). According to Parrot, this condition persists to the 10th year (for congenital hypertrophy see p. 96).

False hypertrophy in a clinical sense is the enlargement which takes place at the expense of the musculature, which is thin, *i.e.*, dilated. We can speak of it pathologically-anatomically, if, for instance, tumors or an echinococcus cyst, cause cardiac enlargement.

For hypertrophy to occur it is necessary to have abundant nutrition; the muscle is reddish brown, often somewhat glassy and of the consistency of rubber.

The muscle fibres are increased in volume and thickness (Goldenberg, Tangl, Romberg and others); perhaps also an increase of fibrillae takes place. The nuclei enlarge (multiplication, division is absent, see Wideroe). [According to Karsner, Saphir and Todd, there is little hyperplasia, most of the increase in size is due to hypertrophy. There seems also to be a maximum beyond which the fiber cannot increase in size. In atrophy there is both diminution in numbers and size. *Am. J. Path.*, 1, 351, 1925.—*Translator.*]

The interstitial tissue, especially its content of elastic fibres, is also increased (Melnikow-Raswedenkow). According to Dietrich the cross striae and cement lines are further apart.

#### DEVELOPMENT OF HYPERTROPHY AND DILATATION

Hypertrophy and dilatation are the results of maladjustment between the work to be accomplished, and the primary mass of functioning muscle substance. Such disproportion is caused, *e.g.*, by stenosis of the ostiae which causes chiefly eccentric hypertrophy, or by valvular insufficiency, which causes chiefly dilatation. In hypertrophy, this disproportion is overcome by muscular growth supported by abundant nourishment; the balance is maintained, at least for some time, through the utilization of reserve power (O. Rosenbach), perhaps even through gain of new reserve energy. Hypertrophy results from increased work of the heart, but with insufficient nutrition, or with steadily increasing work, the reserve power is exhausted, (see Schluter), the muscle yields, and the cavity distends.

According to Horvath, the actual cause of hypertrophy is excess of muscle tonus, *i.e.*, the muscle is more markedly distended and under greater tension. In general, hypertrophy is more frequent in youthful, well nourished individuals while dilatation occurs in older, poorly nourished individuals.

In children, hypertrophy develops very quickly under certain conditions, for the growing young heart with its large capacity for accommodation, offers in its normal growth, the prototype of physiological compensatory hypertrophy.

If progressive hypertrophy fails, early or late, the regressive state sets in, "decompensation" and dilatation begin, and the overworked, insufficient muscle undergoing vacuolation, granular and fatty degeneration (secondary fatty heart), will fail suddenly or gradually; or, the hypertrophic heart muscle ceases its work without an anatomically recognizable cause as far as our present means can determine. Death is caused by cardiac paralysis quickly, or with increasing pulmonary edema (respiratory paralysis).

Krehl and Romberg in explaining insufficiency of the hypertrophic heart muscle probably lay too much stress on secondary complicating interstitial and muscle changes, and Tawara and Aschoff, Stein and others have opposed their view. But whether failure of an hypertrophic heart can be explained by non-cooperation of the muscle fibres of the stimulus conducting system is still doubtful (see Low, lit.). In opposition to Stadler, who explains insufficiency in valvular disease by myofibrosis, (Dehio), *i.e.*, a progressive connective tissue proliferation, and against the supposition of Albrecht, that the hypertrophic heart always shows severe changes, it must be emphasized that sometimes no pathological change of any kind can be demonstrated in a paralyzed heart muscle. At all events, it is questionable whether the occasional positive findings which Babes reports (connective tissue increase; but different from the connective tissue cicatricial substitution in the diphtheria heart, see p. 61) should always be viewed as important in cases of cardiac death, but we might accept it for extensive fatty degeneration (lit. by Schluter, Eugen Albrecht, Lissauer and others, C. Hirsch, Fahr).

**Special causes of hypertrophy and dilatation are:** (a) In the right heart, pulmonary changes with difficulties in circulation through the pulmonary artery, especially from focal narrowing or obliteration as in emphysema, chronic interstitial pneumonia, left heart lesions, bronchial catarrh, bronchiectasis, anthracotic induration of the bronchial lymph nodes which causes narrowing of bronchi and pulmonary vessels, especially veins, pleuritic exudates, pneumothorax of some duration (Bruns), scarred adhesions of the pleural layers, thoracic distortion, especially kyphoscoliosis which leads to decrease in size of the chest cavity and of the compressed lung and in which there is also slight left hypertrophy. They are rarely due to primary sclerosis of the pulmonary artery, but Sanders, Hart, Krutzsch (lit.) point out that even the smallest branches of the pulmonary artery must be taken into consideration (see also Schutte).

Not rarely, there is a secondary "wearing out" sclerosis under the conditions named, which causes circulatory difficulty and pressure increases in the pulmonary artery (see W. Fischer).

If no hypertrophy develops in spite of obstruction in the lung, as we frequently find in phthisis, although not always (Reuter, Wideroe), because in chronic cases it does become hypertrophic, it is perhaps due to insufficient nutrition of the muscle or to the decrease in the quantity of blood so frequently observed in pulmonary tuberculosis and consequently the work of the heart is not increased. The dilatation is often considerable, (for hypertrophy in pertussis, see Brick).

(b) Causes of hypertrophy and dilatation of the left heart are valvular lesions chiefly of the aorta; arterio-sclerosis, as a cause, is inconstant, (see Marchand). Distension of the aorta is responsible for some degree of cardiac changes, (Wideroe). They occur in aneurysms of the ascending aorta, if they open wider the aortic ostium (see p. 42), or if the valves are sclerotic (see Lehmacher). They develop in chronic renal diseases, especially in the true arterio-sclerotic contracted kidney which is particularly combined with hypertony, even in the earliest stages, when the disease is recognizable only microscopically. They are present also in the nephritis of measles and of scarlet fever after several weeks duration in which the right ventricle also becomes hypertrophic, although to lesser degree.

(According to Wiesel, Aubertin, and Clunet, left cardiac hypertrophy occurs in medullary hyperplasia of the adrenals.)

(c) Hypertrophy in both halves of the heart or a small section of them; besides valvular lesions there are tissue changes of the myocardium (fatty degeneration, scars in the muscle), pericardial synechiae, adhesions of the pericardium and the mediastinal connective tissue, chronic renal diseases (see above), from chronic pressure to the ureters with subsequent hydro-nephrosis; (see above), kyphoscoliosis as causes of hypertrophy. In the so-called idiopathic cardiac diseases, there are dilatation and hypertrophy of the cavities and walls without valvular lesions, or impeded circulation from a pulmonary, renal, (requires microscopic investigation), or vascular disease. We doubt the existence of a purely idiopathic cardiac hypertrophy.

Hypertrophy is physiological if it develops as an adjustment to increased labor (in heavy labor and certain sports), and according to Krehl-Hirsch, it is only a proportional increase in the weight of the heart corresponding to the increase in the bodily musculature. It develops without difficulties or symptoms; when the latter appear, it becomes pathological. This so-called idiopathic dilatation and hypertrophy is seen sometimes in persons occupied with very hard work (laborer's heart)

especially when free, deep, breathing is impeded (boatmen, porters, packers, mine-workers, etc.) and when also, to use an expression of Seitz, an excessive task is demanded of the heart. The hypertrophy in these cases may be enormous, (bucardia); Baumlein saw a heart weighing 540 gms. in a 31 year old acrobat (see also Hasebroek). The so-called Tübingen heart (Munzinger) of the hard working vintners of Tübingen, belongs to this class.

In other cases, there are anemia, chlorosis, or previous severe diseases (typhoid, diphtheria, see p. 61) causing weakness of the myocardium which leads to acute dilatation from but moderate over-exertion without preceding hypertrophy. The heart may readjust itself during rest, but eventually will cause death, perhaps suddenly. This may occur with assumed healthy hearts after forced marching, mountain excursions, sport activities, bicycle riding, etc.

In plethora, which, among other causes, is sometimes due to excessive beer drinking, there not infrequently develop hypertrophy and dilatation in individuals, who, at the same time, are doing hard physical labor, (Munich beer heart); in the majority of cases, there are no anatomical changes in the heart muscle. The physical action of large quantities of fluid which are added indirectly to the blood, the toxic action of the alcohol, (see also v. Otto), and the nutrient qualities of beer must all be considered (Bollinger), a conception which, however, often encounters skepticism from the clinical side, (lit. by Thorel). Arterio-sclerosis and kidney contraction are thought of as contributing factors, (see, *e.g.*, Kraus, Hecht). Moenckeberg classes the "beer heart" as well as the Tübingen heart among the cardiac hypertrophies caused by hypertony; the kidneys, he says, without necessarily having developed to the picture of contraction, nevertheless show arterio-sclerosis. But only numerous observations will enable us to answer all these questions with any certainty. Other cases are considered due to abuse of spirits in other forms, to nicotine, coffee, or even nervous influences. Purely psychic influences on heart action (see Tendeloo) are also held responsible for hypertrophy, but, on the other hand, they may also explain severe diminution of the working capacity of the heart.

Cardiac hypertrophies occur with goiter as partly mechanical from impeded respiration and partly thyreotoxic as in Basedow's disease where there is also increase in blood pressure. (caused by excess adrenalin in the blood?, see Minnick, His, Kraus, Scholz). See under thyroid gland.

#### **Changes in the Shape of the Heart in Hypertrophy and Dilatation**

In ventricular hypertrophy, the trabeculae become rounded, project, the recesses are deep, the papillary muscles are thick and appear shorter.

In auricular hypertrophy, the pectinate muscles become conspicuous as prominent combs (fig. 30).

In ventricular dilatation, the trabeculae are flattened, the papillary muscles narrow, thinned and pulled out lengthwise.

In hypertrophy of the right ventricle, the external appearance of the heart changes so that the right ventricle is turned toward the left, and in observing the heart in situ, the left ventricle and especially its auricle become more or less invisible. In high degrees, the right ventricle alone is the apex situated lower than normal. The heart has essentially increased in width, chiefly at the base, it becomes plump, more nearly square, relatively shortened, the apex is broad, the corners rounded and perpendicular to the midline.

If hypertrophy of the left ventricle predominates, the apex of the heart is formed practically by the left ventricle, and is displaced to the left. The papillary muscles "ride" upward, the intrapapillary space is enlarged (details by Kirch). The heart becomes long, cylindrical or conical in shape. If the right ventricle which appears like an appendix of the left is opened, it looks flattened because the ventricular septum bulges into it, (cross sections through the heart like fig. 20, are very instructive). In pronounced dilatation of the left ventricle, *e.g.*, in aortic insufficiency, the apex broadens (fig. 13), becomes spherical, and gives the ventricle the appearance of a pumpkin, (details by Kirch).

In reference to cardiac hypertrophy with experimental aortic insufficiency, see Stewart, lit.

In general hypertrophy and dilatation (so-called total cardiac aneurysm) the heart becomes spherical and so large that comparison with a bullock's heart is justified (*cor bovinum, bucardia*); its weight may be four times the normal and more.

Quite extreme enlargement occurs in congenital lesions, especially defects of the septum (persistent foramen ovale). Herzog saw a heart the size of 5 fists in a 22 year old girl, and in a case of Sternberg, the heart of a 16 year old boy had a cross circumference of 46 centimeters. Hypertrophic hearts repose at a lower level with their apex to the left, and, as a whole, across the diaphragm, causing displacement of both diaphragm and lungs.

### **Thrombus Formation in the Heart**

(APPENDIX. POST MORTEM CLOTS)

We have previously stated that thrombi form in the heart, as in endocarditis, in which the materials are precipitated on the altered valves, *e.g.*, valves showing fatty degeneration (valve thrombi). They also occur in various places in which the walls (endothelium or muscle), have undergone

changes in some manner, as ulcerations and aneurysms (parietal thrombi). We see them in trauma, *e.g.*, where a surgeon placed a suture, but thrombosis may not occur at all in either the heart or the valves. There is a special kind of parietal thrombus, the so-called cardiac polyps, which are differentiated from other thrombi by their globular or polypoid form. These are found in the ventricles between the trabeculae, mostly toward the apex, (fig. 31), more frequently in the right than in the left ventricle (hypertrophic, and then fatty degenerated and dilated) as well as in the dilated auricular appendages.

They begin as white thrombi (platelets-leucocytes-fibrin) within the recesses between the trabeculae and grow in layers upward as new masses from the blood are continually deposited, (ribbed arrangement). Their

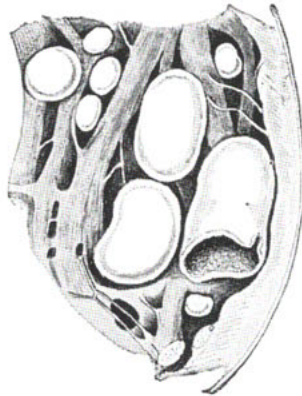


FIG. 31.—Globular and spherical parietal thrombi between the trabeculae of the markedly dilated right heart. To the right a centrally softened thrombus with contents washed out; nat. size.

upper surfaces become rounded, usually hemispherically, (especially in the ventricles); they are usually smooth, but sometimes delicately ribbed, especially in the auricles, and they project like buttons (*boutons du coeur*) into the cardiac cavity. They may grow to the size of a walnut. Thrombi which form in the auricular appendages between the pectinate muscles soon protrude like polyps into the auricle almost completely filling it. They are arranged in layers, or are more uniformly mixed, with ribbed or smooth surfaces (figs. 32 and 33).

Button-like thrombi may undergo decomposition, soften by autolysis, and then contain a creamy yellowish, or white, or chocolate colored mass; they may break or tear open, evacuate, and leave cavities the size of a bean; embolism may follow. The ancients called these softened thrombi, "pus bags," on account of the puriform appearance of the contents.