PATHOLOGIC ALTERATIONS IN THE SYNOVIAL FLUID AND JOINTS OF CATTLE

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
Rollo Winslow Van Pelt, Jr.
1965

This is to certify that the

thesis entitled

PATHOLOGIC ALTERATIONS IN THE SYNOVIAL FLUID

AND JOINTS OF CATTLE

presented by

Rollo Winslow Van Pelt, Jr.

has been accepted towards fulfillment of the requirements for

Ph.D. **degree in** Pathology

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Date February 17, 1965

ABSTRACT

PATHOLOGIC ALTERATIONS IN THE SYNOVIAL FLUID AND JOINTS OF CATTLE

by Rollo Winslow Van Pelt, Jr.

Synovial fluid specimens from 117 joints of 82 cattle of various breeds, ages, and sexes affected with a wide variety of joint diseases were investigated. Where applicable, synovial fluid values were compared with their respective whole blood or serum values.

Pathologic synovial effusions were classified on the basis of anamnesis, clinical symptomatology, etiology, pathogenesis, arthrographs, laboratory analyses, and bacteriologic studies. Hematologic studies were employed to ascertain the systemic effect, if any, exerted by the various types of joint disease.

Group I--Synovial Effusions that Resemble Normal Synovial Fluids: Synovial effusions in this group were transudative in nature. Effusions from cattle affected with degenerative joint disease were slightly in excess of normal volume, whereas effusions from cattle affected with tarsal hydrarthrosis were greatly in excess of normal volume; however, these effusions most closely paralleled normal synovial fluid with respect to their various constituents in

contrast to effusions from cattle affected with acute and chronic traumatic arthritis. Synovial effusions from cattle affected with acute and chronic traumatic arthritis were slightly in excess of normal volume and generally serosanguineous to hemorrhagic in nature. Relative viscosity values for the group fell slightly below normal. Tests for quality of mucinous precipitate indicated a hyaluronic acid content with a relatively high degree of polymerization. Synovial fluid sugar levels closely paralleled blood sugar levels for cattle affected with degenerative joint disease and tarsal hydrarthrosis, but exceeded their blood sugar levels for cattle affected with acute or chronic traumatic arthritis.

Synovial fluid alkaline phosphatase activity with the exception of cattle affected with tarsal hydrarthrosis, exceeded that of its serum counterpart. Lactic dehydrogenase activity, glutamic oxalacetic and glutamic pyruvic transaminase activity for synovial fluid, was found to be less than the activity of their serum counterparts for cattle affected with degenerative joint disease and tarsal hydrarthrosis. Total synovial fluid leukocyte counts for all cattle in this group were slightly higher than normal values.

Group II--Intermediate Synovial Effusions: Synovial effusions from cattle affected with an idiopathic arthritis were exudative in nature. Attempts to culture bacteria from the effusions met with no success. Total volume was in excess of normal, relative viscosity was reduced, and tests

for mucinous precipitate indicated a low degree of hyaluronic acid polymerization or a low ratio of hyaluronic acid to unit volume. Mean synovial fluid sugar levels were found to be 32.7% lower than their blood sugar levels. Synovial fluid lactic dehydrogenase activity, glutamic oxalacetic and glutamic pyruvic transaminase activity were higher than reported normal synovial fluid values for cattle. Total leukocyte counts and the absolute number of neutrophils were greatly increased.

Group III--Septic Synovial Effusions: Synovial effusions from joints with infectious arthritis were exudative in nature. Total volume was greatly in excess of normal, relative viscosity was reduced and tests for mucinous precipitate indicated a hyaluronic acid content of an extremely low degree of polymerization or almost complete absence of the hyaluronic acid complex. Synovial fluid sugar levels were 48% lower than their blood sugar levels. Alkaline phosphatase activity for synovial fluid was in excess of its serum counterpart, but did not attain the mean level for normal cattle. Total leukocyte counts and the absolute number of neutrophils were greatly increased. Infectious arthritis was reflected systemically by a granulocytosis in the peripheral blood.

Gross pathologic and histopathologic studies were performed on 76 joints of 32 cattle. Joint specimens were obtained at necropsy or by punch-biopsy.

The most significant gross lesions in degenerative joint disease were confined to the articular cartilages. The most characteristic findings were a yellowing and thinning of the articular cartilages, with irregular depressions, flaking, pits, and linear grooves. Microscopically, there was a loss of the hyaline appearance of the cartilage, a reduced number of chondrocytes, and fibrillation of the matrix.

The principle gross pathologic lesions in chronic traumatic arthritis were confined to the synovial membrane and consisted primarily of subintimal hemorrhages. Microscopically, subintimal hemorrhage and edema were the most consistent findings.

The joints of cattle affected with an idiopathic synovitis or arthritis were found to resemble infectious arthritis both grossly and microscopically.

Streptococcus viridans was isolated most frequently from joints of cattle with infectious arthritis. Gross and histopathologic lesions varied directly with the virulence of the microorganism. The most severe joint infections were associated with chronic infectious arthritis due to Corynebacterium pyogenes.

Attempts to culture bacteria from the joints of cattle affected with a polyarthritis associated with

primary systemic infections met with no success. Hematogenous spread of bacteria from primary sites of infection or hypersensitivity to the bacterial infections were considered the exciting cause in the production of polyarthritis.

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Pathology

1965

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. R. F. Langham for his guidance and assistance throughout this investigation.

My sincere thanks and appreciation is expressed to Dr. G. H. Conner, Department of Surgery and Medicine for his generous assistance with various aspects of this investigation.

The author wishes to express his appreciation to Dr. C. C. Morrill and Dr. S. D. Sleight for their critical reading of this manuscript and to various members of the Department of Pathology for their assistance with various aspects of this investigation.

Thanks and appreciation are expressed to Mrs. Carolyn R. Easter and Mrs. Joyce A Wilfong, Department of Surgery and Medicine for their assistance with the laboratory analyses of specimens. To Mrs. Marian V. Bennett, Department of Microbiology and Public Health for advice and assistance with specimens for bacteriologic studies.

For awarding a Postdoctoral and Special Fellowship my sincere appreciation and thanks is extended to the National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, Bethesda, Maryland.

Dedicated

to

Karen

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I. INTRODUCTION

The subject of arthritis has received only limited attention in veterinary medicine. Thus any system of classification and nomenclature applied to the various arthritides of domestic animals has not been clearly or adequately defined. With this in mind, this investigation was conducted with the purpose of not only evaluating whole blood, serum, and synovial fluid constituents, and joint tissues of cattle affected with a wide variety of joint diseases, but to develop a system of classification and nomenclature based on etiology, pathogenesis, pathognomy, and pathologic findings.

The synovial fluid of diarthrodial articulations serves not only as the primary source of nourishment for the articular cartilages, but also serves a mechanical function in the nature of a lubricant to the joint surfaces due to its mucopolysaccharide content. The various constituents of normal synovial fluid therefore serve to reflect a joint that is functioning in a normal physiological and mechanical manner. Pathologic synovial effusions reflect changes with the onset of joint disease; such effusions in turn are a reflection of the pathologic processes taking place in the synovial membranes and articular cartilages, thus in turn

producing a disturbance in normal intra-articular metabolism.

Analyses of pathologic synovial effusions should then reveal: (1) an abnormal exchange between blood, lymph, and the synovial fluid; (2) pathologic alterations in intra-articular metabolism; and (3) variations in the degree and duration of the various types of joint disease in cattle. Essential to a basic understanding of pathologic joint effusions is a fundamental knowledge of normal synovial fluid and intra-articular physiology. The objectives of synovial fluid analyses as supported by comparative studies of whole blood and serum analyses in this investigation were to establish: (1) etiology; (2) diagnosis; (3) prognosis; and (4) determine the degree and duration of the pathologic effusion.

Anamnesis, clinical observations, gross pathologic observations, and histopathologic observations of cattle affected with various types of joint disease were conducted to establish a greater degree of correlation among the various parameters of a specific type of joint disease. Only after careful evaluation of the various findings can a system of classification and nomenclature for arthritis in cattle be developed.

II. REVIEW OF THE LITERATURE

Synovial Fluid

Cornelius (1963) pointed out that articular afflictions rank high among the crippling diseases of domestic animals. However, he observed that little or no attention had been given to the cellular and chemical analyses of pathologic joint effusions in veterinary medicine.

Van Pelt and Conner (1963a, 1963b, and 1963c) investigated the cytologic properties, relative viscosity, quality of mucopolysaccharide, and the sugar level of synovial fluid from the tarsal joints of normal cattle (Table 1).

Davies (1944) observed that normal synovial fluid from the tibiotarsal joints of cattle often varied from a pale-yellow to a deep-yellow in color. However, he made no attempt to determine the nature of the pigment or pigments present.

The relative viscosity of normal synovial fluid from the tibiotarsal joints of cattle has been reported by various investigators employing a wide variety of viscosimeters. Ropes et al. (1939), employing either a Hess or Ostwald viscosimeter, reported a mean relative viscosity of 3.72 at 25 C., while Spector (1956) reported a value of 5.0

TABLE 1. Summary of Selected Physical, Cytologic, and Chemical Properties of Synovial Fluid from the Normal Bovine Tarsus*

	Range	Mean
Volume (cc./joint)	4 to 20	12.6 ± 0.5
Color - colorless to pale-yellow, and clear (an occasional sample may contain some minute flocculent debris)		
Relative viscosity at 38.6 C.	1.63 to 13.01	3.79 ± 0.28
Total leukocytes/cmm.	0 to 725	103.50 ± 14.23
Differential count (%)		
Neutrophils	0 to 69	6.00 ± 1.24
Lymphocytes	2 to 92	49.08 ± 2.77
Monocytes	2 to 86	38.22 ± 2.47
Macrophages	0 to 48	5.93 ± 1.38
Eosinophils	0 to 9	0.77 ± 0.22
Sugar - approximately the same level as whole blood		
Alkaline phosphatase activity (Sigma Units/ml.)	0.00 to 12.90	5.07 ± 0.47
Lactic dehydrogenase activity (LDH Units/ml.)	0 to 905	209 ± 22
Glutamic oxalacetic transaminase activity (Sigma-Frankel Units/ml.)	0 to 88	30.36 ± 2.53
Glutamic pyruvic transaminase activity (Sigma-Frankel Units/ml.)	0 to 75	15.98 ± 1.79
Fibrinogen	0	0

*Van Pelt and Conner (1963a, 1963b, and 1963c) and Van Pelt (1964).

as determined with a Hess viscosimeter at 20 C. Van Pelt and Conner (1963b) found the relative viscosity of synovial fluid from the tibiotarsal joints of 73 normal cattle to be 3.79 ± 0.28 at 38.6 C. (Table 1), employing either a Cannon-Fenske routine viscosimeter or a Cannon-Ubbelohde semi-micro viscosimeter.

Fessler et al. (1954) pointed out that the viscosity of human synovial fluid was due to the presence of hyaluronic acid and that slight changes in the hyaluronic acid molecule noticeably affected the velocity gradient. Levine and Kling (1956) found the rheologic behavior of synovial fluid to provide valuable information concerning the physiologic and pathologic nature of the joints.

Gardner (1953 and 1959) determined that the viscosity of synovial fluid decreased exponentially as the synovial fluid was diluted with water. Jebens and Monk-Jones (1959) found that synovial effusions from traumatic knee joints evidenced a reduction in viscosity. They attributed reduced viscosity to transudation of plasma from subsynovial blood vessels into the joint cavity in response to injury, the transudative nature of the effusion acting as a diluent to the synovial fluid. They concluded that only a rapid and simultaneous increase in the production of hyaluronic acid could prevent such a transudate from acting as a diluent. Sunblad (1953) showed that the concentration of hyaluronic acid in effusions from traumatized joints varied approximately

in an inverse ratio to the volume of the synovial effusion.

Ropes and Bauer (1953) stated that the concentration of hyaluronic acid in joint disease was related to the type, severity, and duration of the disease and the duration of the synovial effusion. The lowest concentrations of hyaluronic acid were in severe cases of infectious arthritis or rheumatoid arthritis.

Meyer (1947) and Ropes et al. (1947) were not successful in their attempts to demonstrate the presence of a mucinase or hyaluronidase, or similar enzyme in pathologic synovial effusions. Robertson et al. (1940) allowed sterile normal and pathologic synovial effusions to stand for varying periods of time at 25 C. and 37 C., and observed no decrease or alteration in the hyaluronic acid content. The addition of anaerobic cultures of Clostridium perfringens to the synovial effusions resulted in depolymerization of the hyaluronic acid. Carpenter (1959) stated that hyaluronidase was formed by Cl. perfringens, streptococci, pneumococci, certain micrococci, and other microorganisms.

Moffett (1954) demonstrated that the permeability of the synovial membrane allowed the passage of fluids and colloids in either direction between the joint cavity and the synovial blood vessels, lymphatics, and surrounding tissues.

An increase in the effusion of a traumatized joint or joints, according to Collins (1936), was not always due

to hemorrhage into the joint cavity. In many cases the increased volume was due to transudation of blood plasma from the subsynovial vessels.

Bauer et al. (1940) pointed out that experimental studies with animals demonstrated the permeability of the barrier between blood vessels and the joint cavity, not only to diffusible substances and proteins, but to bacteria as well. Permeability of the synovial membrane was greater than that of membranes in other body cavities. Balboni et al. (1945) found that penicillin passed readily into the synovial fluid following its intramuscular administration.

DeGara (1943) investigated the bactericidal properties of synovial fluid and found that the bactericidal activity for Gram-negative bacteria was closely related to the complement content of the synovial fluid and that bactericidal activity may therefore be expected in effusions containing sufficient amounts of complement.

Ropes and Bauer (1953) determined that variations in the concentration of sugar, in contrast to those of other nonelectrolytes, are of diagnostic value in joint diseases. They reported lower sugar values for hemorrhagic effusions from the knee joints of man as the result of an increased glycolytic enzyme activity associated with large amounts of blood in the joint.

Fury et al. (1959) stated that normal sugar levels for man should not exceed that of their respective normal synovial fluid sugar levels by more than 20 mg./100 ml. in the fasting state. Any difference greater than this indicated a pathologic process in the joint.

Cajori and Pemberton (1928) demonstrated that the glycolytic activity of cell-free synovial fluid was much less marked than uncentrifuged synovial effusions containing a large number of leukocytes. The presence of glycolytic enzymes in synovial effusions was found by Hubbard and Porter (1943) to be confined almost entirely to the neutrophilic leukocytes. Levene and Meyer (1912) found that a sugar solution will lose a portion of its reducing power under the influence of high leukocyte counts. On the other hand, Collins (1936) found no correlation between total leukocyte counts and the sugar level of synovial effusions. In man, Ropes et al. (1960) showed that the degree of initial lag and the reduction in subsequent rate of sugar entrance into the joint cavity increased with the severity of the joint disease. Meyers et al. (1934) noted that synovial effusions from joints affected with gonococcal arthritis contained high total leukocyte counts, and that the higher the total cell count, the lower the sugar level. The presence of microorganisms in synovial effusions also produced a lower sugar level in spite of low total leukocyte counts.

Ropes and Bauer (1953) found the alkaline phosphatase activity of normal cattle synovial fluid to be much higher than the alkaline phosphatase activity of the serum. They determined a mean value of 13.8 Bodansky units/100 ml. of synovial fluid in contrast to 4.6 Bodansky units/100 ml. of serum. Van Pelt (1964) determined a mean alkaline phosphatase activity of 5.07 $\pm$ 0.47 Sigma units/ml. for synovial fluid and 1.67 $\pm$ 0.14 Sigma units/ml. for serum from dairy cattle ranging in age from 1 to 10+ years (Table 1). Enzyme activity in the synovial fluid and serum decreased with advancing age. Allcroft and Folley (1941) observed that serum alkaline phosphatase activity in cattle progressively decreased with advancing age until maturity was reached. Thereafter cattle had little or no alteration in their serum alkaline phosphatase activity. They could establish no correlation between milking capacity and serum alkaline phosphatase activity in dairy cows. Working with Zebu cattle, Garner (1952) observed little variation in serum alkaline phosphatase activity after two years of age. Negi (1960) attributed variations in serum alkaline phosphatase activity of cattle to varying nutritional and physiological conditions. Robertson *et al.* (1940) demonstrated *in vitro* that serum alkaline phosphatase will slowly hydrolyze synovial mucin. They obtained serum with a high alkaline phosphatase activity by ligation of the common bile duct in a dog.

Studies in man by Lehman et al. (1964) demonstrated that there are no significant differences in synovial fluid alkaline phosphatase levels between the inflammatory and noninflammatory arthritides. The alkaline phosphatase activity of the synovial fluid was lower than that of the serum.

The source of alkaline phosphatase activity in synovial fluid is apparently derived from several sources within the joint. Shaw and Marten (1962) were unable to demonstrate the presence of the enzyme in either synovial intimal cells or the intercellular fibers of the synovial membrane, or in the precipitated synovial fluid from a variety of mammalian knee-joint tissues. They demonstrated enzyme activity in the hypertrophic cartilage adjacent to areas of bone formation. This reaction was localized in the enlarged chondrocytes, the extracellular material in the lacunae, at the lacunar margins, and in the cartilagenous matrix around the lacunae. Intense cytoplasmic reactions were obtained in the osteoblasts and in the heterophils of guinea pigs.

Studies on the presence of alkaline phosphatase activity in the leukocytes of pathologic joint effusions from cattle were made by Van Pelt (1961b). The synovial fluid from septic joints contained many alkaline phosphatase-positive polymorphonuclear neutrophils in conjunction with a high synovial fluid alkaline phosphatase activity. Wiltshaw and Moloney (1955) observed that in pyogenic

infections the leukocytes showed greatly increased alkaline phosphatase activity. Kenny and Moloney (1957) reported that prolonged incubation of neutrophils resulted in an increased alkaline phosphatase activity within the cell. Schajowicz and Cabrini (1954) found increased alkaline phosphatase activity in osteogenic areas and in cartilage undergoing calcification. Hypertrophied cartilage cells and the cells which produce the intracellular substances of bone (osteoblasts) produced large amounts of alkaline phosphatase activity, according to Ham (1957). Kleiner (1954) has pointed out that elevated serum alkaline phosphatase activity may be due to overproduction of the enzyme in bone in order to compensate for various lesions, or to forced extrusion of the enzyme from injured bony tissues. Septic tissues and tissues surrounding areas of sepsis were found by Steward and Beckett (1959) to contain increased amounts of alkaline phosphatase.

West et al. (1963) reported that the lactic dehydrogenase activity of synovial fluid from human knee joints affected with degenerative joint disease was comparable to that of normal human synovial fluid. There was a significant correlation between the number of leukocytes in synovial effusions and the lactic dehydrogenase activity of the effusion. It was concluded that increased lactic dehydrogenase activity in synovial effusions might have resulted

from: (1) release of the enzyme from leukocytes in the synovial effusion; (2) release of the enzyme from necrotic or inflamed synovial tissues; or (3) production and release of an increased amount of enzyme by altered synovial tissues. Vesell *et al*. (1962) found the lactic dehydrogenase activity of synovial effusions from patients affected with rheumatoid arthritis to exceed that of their respective serum values. They postulated that elevated lactic dehydrogenase activity in synovial effusions may have its source either in the leukocyte, or the synovial membrane, or both.

The synovial fluid glutamic oxalacetic transaminase activity for patients affected with degenerative joint disease was found by West *et al*. (1963) to be within normal limits for synovial fluid. Abnormal values were found in approximately 50% of the patients affected with rheumatoid or pyogenic arthritis. Cornelius *et al*. (1959) reported a mean value for serum glutamic oxalacetic transaminase activity of 43.8 $\pm$ 5.7 Sigma-Frankel units/ml. for Holstein-Friesian cattle ranging from 2 to 10 years of age. They also reported a mean serum glutamic pyruvic transaminase value of 19.7 $\pm$ 12.6 Sigma-Frankel units/ml. for the same group of cattle.

Wheat (1955) made observations on synovial fluid obtained from cattle and horses and noted that if aspirated synovial fluid was clear and viscid, it was usually sterile

and the effusion was generally due to trauma or strain. Stained smears of synovial fluid from these joints had few leukocytes, usually 100 or less per cubic millimeter and of the mononuclear type. Joint infection was suspected when the synovial fluid was cloudy and flocculent and had less than normal viscosity. Gram-stained smears of this type of synovial fluid revealed counts of 5,000 to 10,000 or more leukocytes per cubic millimeter, with an increase in the absolute number of neutrophils. In such cases, he advised a bacteriologic examination of synovial fluid. His observations revealed that Streptococcus spp. were commonly encountered in infected joints.

Lange (1961) found the use of synovial fluid cytologic studies in joint diseases of cattle of value as a diagnostic aid, as well as a means of making a prognosis regarding the particular joint condition.

Bauer et al. (1930) reported that 90 to 95% of all nucleated cells in the synovial fluid of cattle were phagocytic for particulate matter, cells, and fragments of cells. They demonstrated by supravital techniques that the function of phagocytic synovial cells was the removal of products of wear and tear from the articular cartilages and synovial membranes.

Joint Tissues

Bennett and Bauer (1931) investigated degenerative joint disease in cattle. They concluded that areas of degeneration in the articular cartilages of the carpometacarpal articulations of all cattle over two years of age was apparently an adequate explanation for the differences observed between the synovial fluid from this joint and that of the tibiotarsal (astragalotibial) joint. They further pointed out that the types of articular cartilage lesions observed were not wholly similar to any of the joint lesions described for degenerative joint disease of man.

Evidence of degenerative joint disease (osteoarthritis) in the femoropatellar and femorotibial articulations (gonitis) was observed by Frank (1953) to be indicated by a distention of the joint capsule. Severe claudication and distention of the joint capsule were associated with extensive ulceration of the articular cartilages.

Old bulls with impaired fertility were found by McEntee (1958) to have degenerative changes in the articular cartilages of various joints. Degenerative joint lesions and vertebral exostoses were regarded as the cause of a certain amount of locomotor disturbances.

Fowler and Kingrey (1956) reported that degenerative joint disease (osteoarthritis) of the bovine tarsus may be associated with the degenerative changes of advanced age.

They reported degenerative joint disease to be fairly common in aged bulls, probably in part because of their great body weight and sometimes because of limited exercise. Roughening of the articular surfaces and periarticular lipping (osteophytosis) were frequently encountered. Radiographs of the tarsus in old bulls revealed a considerable amount of this type of lesion, even in animals showing no evidence of claudication. As the development of osteophytes advanced, however, claudication and gross enlargement of the tarsus resulted. They related faulty limb alignment to the development of degenerative joint disease in early life. Younger animals so affected revealed on radiographs an overextension of the tarsal joint. They suggested that this condition could be congenital or result from a mild case of rickets when the animal was young.

Shupe (1959) reported that, in general, degenerative joint disease in cattle was unaccompanied by systemic manifestations. Clinically, degenerative joint disease was characterized by pain on locomotion and standing, and was relieved by rest (ventral recumbency). It occurred chiefly in older cattle and was most often observed in the larger, more freely movable joints. In advanced cases, there was an increase in the amount of synovial fluid which contained increased protein, masses of fibrin, sequestra, an increase in the nucleated cell count, and joint bodies (corpora libra).

Shupe (1961) also observed that some of the causes of degenerative joint disease in cattle were secondary in nature and resulted from disuse of the malfunctioning joint or joints.

The onset of degenerative joint disease in aged bulls was reported by Neher and Tietz (1959) to be frequently insidious in nature; however, it appeared to be associated with trauma to a specific joint and later had a tendency to become polyarticular in distribution. Minor remissions and exacerbations were characteristic of the condition, although marked remission of symptoms was frequently observed coincidental with improved climatic conditions. Neher (1960) further observed that synovial effusions in approximately one-third of the cases of degenerative joint disease in cattle were in excess of normal volume and that the viscosity of the effusion was less than normal.

Vaughn (1960) reported that degenerative joint disease (osteoarthritis) in cattle was initiated in the same way and followed the same course as in man. The rate of progress of the disease, however, was more rapid in cattle than in man, because from the time of the initial injury to the joint, the limb was never allowed to rest, and the mechanical forces at play were enormous, particularly in the femoropatellar and femorotibial joints.

Bulls with spastic contraction of the hindlimbs (stretches) were found by Townsend (1961) to have lesions

of degenerative joint disease which he called osteoarthritis. He reported no cure for the condition; however, the intra-articular injection of hydrocortisone gave temporary relief from pain. He concluded that the best control was through prevention, and that bulls with a family history of this condition should not be used in breeding programs. Good management of the individual bull was considered an important factor, making sure that proper exercise was taken and adequate bedding was available, and that physical action which could possibly result in further joint damage be avoided.

Degenerative joint disease, which they called degenerative arthropathy, was described by Blood and Henderson (1963) as occurring unassociated with obvious defects of the bones, particularly in beef bulls and aged dairy cattle. They observed that, when the limb joints were affected, there was evidence of claudication in severe cases, crepitus, and distention of the joint capsule with synovial fluid. Deficiencies or mineral imbalances, particularly of calcium and phosphorous, were suggested by these workers as possible etiologic factors.

Boyd (1961) attributed the reduction and eventual loss of intercellular ground substances with subsequent fibrillation of the remaining cartilage to a loss of chondroitin sulfate from the ground substance. According to Moore (1952), further articular attrition resulted when joint movement destroyed the soft, partially necrotic

articular cartilage, thus exposing the subchondral bone to grooving and eburnation. Prior to cartilaginous erosion, osteoblasts in the area of the subchondral bone had undergone proliferative changes, with the formation of new bony trabeculae, narrowing of the Haversian canals, thickening of existing subcortical trabeculae, and an invasion of the articular cartilage by the newly formed bone. Such degenerative changes resulted secondarily in the formation of marginal osteophytes in response to increased periarticular stress. Johnson (1962) pointed out that marginal osteophytosis resulted in peripheral or circumferential remodeling of the joint, which resulted in an increased diameter at the ends of the bone in the area of the periarticular margins. Progressive changes consisted of periosteal elevation, and chondrification followed by ossification of the ligaments, tendons, or joint capsules attached to the bone in this area.

Rodnan et al. (1960) observed in man a sclerotic atrophy of the synovial membrane, which consisted of a flattening and associated decrease in the number of synovial intimal cells. In some specimens of synovial membrane they observed a complete absence of the synovial intimal cells, with hyalinization of the stroma. Hyalinization of the stroma was generally homogeneous in nature, while in some specimens the hyalinized stroma was arranged in broad bands that ran parallel with the surface of the stratum synoviale. Associated with sclerotic atrophy of the synovial membrane was

a hyalin thickening of the capillary and arteriolar walls.

Mikkelsen et al. (1958) observed a minor hyperplasia of the synovial intimal cells, with a scattering of inflammatory cells in the stratum synoviale of the synovial membrane specimens obtained from the knee joints of man. Schwartz and Cooper (1961) and Collins (1949) observed a scattered subintimal infiltration and associated perivascular cuffing with lymphocytes in synovial membrane specimens from joints affected with degenerative joint disease in man.

Hutyra et al. (1945) described a puerperal arthritis or synovitis associated with parturition in cattle. The joint disease produced a serous, fibrinous, or purulent synovial effusion 6 to 8 days following parturition or, in some instances, later, usually in conjunction with putrefying material in the uterus. The tarsal or carpal joints were most frequently involved. Glättli (1957) stated that puerperal arthritis occurred frequently in the absence of necrotic lochia. He suggested that a saphrophytic contamination of the residual uterine contents occurred and that hypersensitivity to the saphrophytes produced the puerperal arthritis. Sokoloff (1960) pointed out that puerperal arthritis was a relatively common affliction of cattle and regarded the syndrome as being due to dissemination of bacteria from infected decidual sinuses. He concluded that the condition had no pathologic characteristics that would

distinguish it from other types of infectious polyarthritis. A severe, painful form of arthritis or synovitis of a similar nature has been described by Boddie (1962), involving particularly the tarsus in association with septic metritis and mastitis in cattle.

Mikkelsen et al. (1958) described follicle-like collections of lymphocytes and plasma cells in perivascular formations in synovial membrane specimens from patients affected with rheumatoid arthritis; however, they pointed out that no single finding was diagnositic of rheumatoid arthritis. Boyd (1961) attributed the formation of subchondral granulation tissue in rheumatoid arthritis as a response by the epiphyses to the inflammatory processes in the joint.

Fowler and Kingrey (1956) noted an apparent selective localization of pyogenic microorganisms for the tendovaginal sheaths and joints of cattle. Usually the most pronounced involvement was found in the tarsus. Infectious arthritis was especially common in suppurative metritis, suppurative mastitis, and omphalophlebitis.

Crawford and Frank (1940) described a synovitis in yearling bulls following the intravenous injection of viable avian tubercle bacilli (Mycobacterium avium) recovered from swine. Joint swellings developed in 4 of 10 animals, approximately 8 months following the initial intravenous

injection. Avian tubercle bacilli were isolated from the synovial effusions of the affected joints.

A septic arthritis of the tibiotarsal, femoropatellar, femorotibial, and carpal joints of two 8-months-old Hereford steers due to Erysipelothrix insidiosa (rhusiopathiae) was investigated by Moulton et al. (1953). Post mortem lesions were restricted to the joints and large quantities of synovial fluid were observed; there was a marked proliferation of the synovial membranes (extensive villous proliferation), in addition to extensive erosions of the articular cartilages. The ankylosis observed in association with polyarthritis of swine due to E. insidiosa (rhusiopathiae) infections as reported by Sikes (1959) was not observed in either of the two steers.

Smith and Jones (1961) described an acute suppurative or an acute fibrinous arthritis due to wounds or as a result of a generalized septicemia or pyemia. The most common form of infectious arthritis was pyosepticemia of the new-born (pyosepticemia neonatorum) resulting from infection of the umbilicus at birth. The most common etiologic agents of infectious arthritis in cattle were listed by Jubb and Kennedy (1963) as Streptococcus spp., Escherichia coli, Corynebacterium pyogenes, and Salmonella spp. Streptococcal and coliform polyarthritis was generally considered neonatal in origin, while infectious arthritis due to C. pyogenes and Salmonella spp. occurred at any age.

Van Pelt (1962a) isolated C. pyogenes, Staphylococcus aureus, S. fecalis, and E. coli from the synovial effusions of infected joints of cattle of various ages, breeds, and sexes. These microorganisms were introduced to the joint cavity by foreign body penetration, extension from an area of infection adjacent to the joint cavity, associated with a septicemia, or had metastasized from a focus of infection in some other part of the animal's body.

The recovery of Mycoplasma spp., pleuropneumonia-like organisms (PPLO), from the joints, kidneys, and spleen of a calf showing evidence of a severe arthritis and bronchopneumonia was reported by Moulton et al. (1956). The organism was experimentally inoculated into young cattle and resulted in clinical signs of stiffness, claudication, and corneal keratitis. Agglutinins for Mycoplasma spp. were demonstrated in the serum from these animals. Cordy (1959) reported the occurrence of arthritis in ruminants due to Mycoplasma spp. (PPLO), and recovered large numbers of the causative agent from the synovial effusions of infected animals. The atlanto-occipital and larger diarthrodial articulations were most commonly involved. The synovial effusions were yellowish and turbid, but only moderately increased in quantity. Frequently the synovial effusions clotted immediately following collection. As expected, the more severe cases contained large amounts of fibrin, which upon microscopic examination

revealed extensive masses of compacted fibrin interlaced with many disintegrating neutrophils. Simmons and Johnston (1963) reported an arthritis in calves also due to Mycoplasma spp. (PPLO) which, in the initial stages of the disease, was characterized by a fibrino-purulent synovial effusion that became fibrinous in the latter stages of the disease. Arthritic lesions had been completely resolved in the case of one of the calves when a post mortem examination was conducted 5 months following the initial infection.

Coggeshall et al. (1941) investigated synovial fluid and synovial membrane specimens obtained post mortem from patients who had died as a result of a generalized infection and found that the tissues occasionally showed an inflammatory reaction which was reflected by the cytology of the synovial effusion even though microorganisms were not isolated or demonstrated in cultures or histologic sections.

Recently, Wilske and Decker (1965) reported that ulcerative colitis, regional enteritis, and Whipple's disease of man frequently had in common an intestinal disorder, an asymmetrical nondeforming large-joint arthritis and an increased incidence of spinal joint involvement.

III. MATERIALS AND METHODS

The nomenclature and classification of the arthritides, arthroses, and synovites studied in this investigation were based on the work of Blumberg et al. (1964) as established by the Nomenclature and Classification Committee of the American Rheumatism Association.

Blood, Serum, and Synovial Fluid Studies

Samples of synovial fluid were collected from a total of 117 joints of 82 cattle of various breeds, ages, and sexes.

The various types of arthritis, arthrosis, and synovitis encountered in the course of this investigation were diagnosed and classified with the aid of the following criteria: (1) etiology; (2) pathogenesis; (3) pathology; (4) anamnesis; (5) clinical signs; (6) arthrographs; (7) synovial fluid analyses; and (8) bacteriologic studies. In addition to synovial fluid analyses, a complete hemogram was made on the peripheral blood of each animal.

Classification of Pathologic Synovial Fluids

On the basis of the preceding criteria and the results of synovial fluid analyses, the synovial fluids

analyzed in this investigation have been grouped into three major categories based on the work of Ropes and Bauer (1953).

Group I--Synovial Effusions that Resemble Normal Synovial Fluids

These effusions are primarily transudative in nature. Pathologic joint effusions included in this group are the result of degenerative joint disease, osteochondromatosis, osteochondritis dessicans, hydrarthrosis, and traumatic arthritis.

Group II--Intermediate Synovial Effusions

These effusions possess characteristics of both Groups I and III, i.e., they may be transudative to exudative in nature. Pathologic conditions included in this group include acute, subacute, or chronic synovitis and arthritis, arthritis associated with disturbances in metabolism (gout), and hemophilic arthropathies.

Group III--Septic Synovial Effusions

These effusions are exudative in nature and are the result of a specific infectious agent in the joint as identified by bacteriologic examination of the synovial fluid. The effusions may be of variable duration and may be primary (due to penetration of a foreign object into the joint cavity), secondary (extension from an area of infection adjacent to the joint cavity), or tertiary (associated with a septicemia or metastasis from an area of infection in some

other part of the body not adjacent to the joint cavity).

Blood Serum Samples

Whole blood samples for determination of serum alkaline phosphatase activity (ALP), lactic dehydrogenase activity (LDH), glutamic oxalacetic transaminase (GOT), and glutamic pyruvic transaminase (GPT) levels were obtained from the jugular vein by venipuncture prior to arthrocentesis of the respective joint or joints. The clot was allowed to retract at 5 C., and the sample then centrifuged* at 2,500 revolutions per minute (r.p.m.) for variable periods of time at 5 C. in order to obtain the clear supernatant serum. All alkaline phosphatase activity determinations were made on the day blood was collected. Serum for lactic dehydrogenase activity, glutamic oxalacetic transaminase, and glutamic pyruvic transaminase levels was frozen following centrifugation at -25 $\pm$ 2 C. and then stored at -70 $\pm$ 5 C. until analyses were conducted. Hemolyzed serum samples were excluded from the various enzymatic determinations.

Synovial Fluid Samples

Synovial fluid was obtained by arthrocentesis as described by Van Pelt (1961a and 1962b) from the following joints: (1) radiocarpal; (2) intercarpal; (3) metacarpophalangeal; (4) femoropatellar; (5) tibiotarsal; and (6)

*Model PR-2, International Portable Refrigerated Centrifuge, International Equipment Company, Needham Heights, Mass.

metatarsophalangeal. Synovial fluid was collected from the various individual joints and in some instances from the corresponding joints of the opposite limb. All glassware and needles had been previously cleansed and rinsed with distilled water prior to air-drying in a hot oven. Aspiration of synovial fluid was made with sterile 16- or 18-gauge needles of various lengths. Sterile, dry, 5-, 10-, or 20-cc. metal-tipped glass syringes were employed for withdrawal of the synovial fluid. Samples were then transferred immediately to dry, screw-capped vials, one containing no anticoagulant, and the other containing an anticoagulant. That portion of a sample intended for bacteriologic studies was transferred immediately to a sterile vial. Gross appearance and total volume of the synovial effusion were observed and recorded at the time of collection. A minimum quantity of 3.0 ml. was required for a complete analysis. With the exception of that portion of the sample employed for total erythrocyte and leukocyte counts, and bacteriologic studies, all samples were centrifuged at 2,500 r.p.m. for variable periods of time at 5 C. in order to obtain a supernate free of cellular material and debris. All synovial fluid alkaline phosphatase activity determinations were made on the day the sample was obtained. Synovial fluid for lactic dehydrogenase activity, glutamic oxalacetic transaminase and glutamic pyruvic transaminase levels were frozen following centrifugation at -25 $\pm$ 2 C. and then stored at -70 $\pm$ 5 C. until

analyses were conducted. Hemolyzed samples were excluded from the various enzymatic determinations; however, samples that were xanthochromic in nature were employed for enzyme analyses.

Gross Appearance of the Synovial Fluid

The gross appearance of the synovial fluid was classified as follows based on the investigations of Van Pelt and Conner (1963a) and Van Pelt (1963d):

N = normal (colorless and clear)

NF = colorless and clear, with some flocculent material

NO = colorless and opaque

NOF = colorless and opaque, with some flocculent material

Y = pale yellow and clear

YF = pale yellow and clear, with some flocculent material

YO = pale yellow and opaque

YOF = pale yellow and opaque, with some flocculent material

A = amber and clear

AF = amber and clear, with some flocculent material

AO = amber and opaque

AOF = amber and opaque, with some flocculent material

TY = turbid and yellow

TYF = turbid and yellow, with some flocculent material

SS = serosanguineous

H = hemorrhagic

Blood and Synovial Fluid Anticoagulants

Two anticoagulants were employed in this investigation to prevent clotting of whole blood and pathologic synovial effusions. Initially in the investigation a 20% aqueous solution of ammonium oxalate and potassium oxalate (APO) (approximately 2 mg./ml. of blood or synovial fluid) was employed. In the latter portion of the investigation, a 10% aqueous solution of dipotassium ethylenediaminetetraacetate* (EDTA) was used to prevent clotting of blood and synovial fluid (approximately 2 mg./ml. blood or synovial fluid). Vials containing the anticoagulant were prepared prior to time of sample collection and the respective anticoagulant solutions evaporated to dryness at 68 C. Ammonium oxalate and potassium oxalate was employed in the latter aspects of the investigation for the collection of synovial effusions intended for alkaline phosphatase activity determinations when the total quantity of synovial fluid was such that there would be an insufficient amount of supernatant following clot retraction and subsequent centrifugation to permit enzymatic analyses.

*Cambridge Chemical Products, Inc., Dearborn, Mich.

Blood and Synovial Fluid Sugars

Whole blood sugar values were determined and evaluated in relation to their respective synovial fluid sugar levels. These values were determined by a modification of the original work of Folin and Wu (1920) and Folin (1926). When quantities of synovial fluid were insufficient to permit analyses by macromethods a micromethod modification of the original technique as described by Hepler (1957) using 0.1 ml. quantities was utilized. Samples were read at 430 mμ in a spectrophotometer* employing 19 x 105 mm. cuvettes for the macromethod and 12 x 75 mm. cuvettes for the micromethod. A standard glucose solution (0.1 mg. of glucose per 1 ml. of a 0.25% benzoic acid solution) was employed for each series of sugar determinations. The sum total of reducing agents in the whole blood and synovial fluid was reported and referred to as sugar in view of the fact that they do not represent glucose per se, as reported by Benedict (1931), Fashena (1933), Fashena and Stiff (1941), Folin and Wu (1920), Folin (1926), and Hepler (1957). All sugar values were expressed in milligrams per 100 ml. of whole blood or synovial fluid. All animals had free access to feed immediately prior to the time of sample collection.

*Model 6-A, Junior Spectrophotometer, Coleman Instruments, Inc., Maywood, Ill.

Relative Viscosity

Relative viscosity of the synovial fluid was determined on the clear supernatant fluid after centrifugation of the sample as described by Van Pelt and Conner (1963b). These determinations were made at 38.6 C. employing either a routine viscosimeter* (A.S.T.M., sizes 100, 150, or 200) for quantities of 5 or 10 ml., or a semi-micro-dilution viscosimeter** (A.S.T.M., sizes 100 or 150) for 1 ml. quantities. The viscosimeters were suspended in a kinematic constant temperature water bath*** (A.S.T.M., No. D445-53T) designed for use with capillary viscosimeters. A constant bath temperature was maintained by a mercury, water vapor-type thermoregulator. Distilled water was employed as the reference liquid for relative viscosity determinations because of its complete stability for such purposes as shown by Cannon (1960). Efflux measurements for synovial fluid were determined with a hand-operated stop watch.

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*Cannon-Fenske Routine Viscometer, Cannon Instrument Company, State College, Pa.

**Cannon-Ubbelohde Semimicro Dilution Viscometer, Cannon Instrument Company, State College, Pa.

***Krebs Constant Temperature Water Bath, Krebs Electric and Manufacturing Company, New York, N.Y.

Mucinous Precipitate

The mucinous precipitate test was performed on the supernatant synovial fluid as described by Van Pelt and Conner (1963b) following centrifugation of the sample. This procedure was performed to determine the degree of polysaccharide polymerization. Clot formation and turbidigenic properties were determined by the addition of synovial fluid in a 1:4.1 ratio to a 2.5% aqueous solution of glacial acetic acid (pH 2.3 at 25 C.). The results were graded as follows: (1) normal (N), a tight, ropy clump in a clear solution; (2) fair (F), a soft mass in a very slightly turbid solution; (3) poor (P), small, friable masses in a turbid solution; and (4) very poor (VP), a few flecks in a turbid solution.

Serum and Synovial Fluid Alkaline Phosphatase Activity

Serum and synovial fluid alkaline phosphatase activity (ALP) were determined by a micromethod as described by Sommer (1954) employing 0.1 ml. quantities of the respective fluids. Samples were incubated at 38 C. for 30 minutes employing p-nitrophenyl phosphate disodium tetrahydrate* (absorption maximum of 400 mμ) as the substrate (buffered with 0.1 M aminoacetic acid to pH 10.5) and the reaction

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*Sigma Chemical Company, Inc., St. Louis, Mo.

stopped by the addition of 10 ml. of 0.02 N NaOH. Samples were then transferred to a 10-mm. rectangular silica cell and read at 410 mμ against a substrate blank (0.1 ml. of double distilled water with less than 1 p.p.m. NaCl was substituted for serum or synovial fluid during the incubation procedures) in a spectrophotometer* at 25 C. and the per cent transmittance recorded. The inherent color of the blank, serum, and synovial fluid was corrected for by the addition of 0.1 ml. of concentrated HCl to each incubation tube. Samples were then read again, against the blank and the second reading recorded and subtracted from the first to obtain the correct alkaline phosphatase activity of each sample. Alkaline phosphatase activity was reported in Sigma units per milliliter of serum of synovial fluid as determined by a standardization curve. One Sigma unit is that amount of alkaline phosphatase activity which will liberate 1 μM (micromol) of p-nitrophenyl per hour at 38 C. (1 μM = 0.1391 mg.).

Serum and Synovial Fluid Lactic Dehydrogenase Activity

Serum and synovial fluid lactic dehydrogenase activity (LDH) were determined by a micromethod based on the work of Cabaud and Wröblewski (1958) employing 0.1-ml. quantities of the respective fluids. Serum was diluted 1:5 with

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*Model D-B Spectrophotometer, Beckman Instruments, Inc., Fullerton, Calif.

double-distilled (less than 1 p.p.m. NaCl) water and synovial fluid was utilized in undiluted quantities. In some instances serum dilutions of 1:29 and synovial fluid dilutions of 1:5 or 1:29 were required. Samples were incubated at 38 C. for 30 minutes in a substrate solution containing 1.0 mg. of beta-diphosphopyridine nucleotide; dihydronicotinamide adenine dinucleotide-disodium (b-DPNH)* and 1.0 ml. of phosphate buffered pyruvic acid (pH 7.6 at 25° C.) and the reaction stopped at the termination of the incubation period by the addition of 1.0 ml. of a 2,4-dinitrophenylhydrazine HCl solution. Color was allowed to develop at room temperature for 20 minutes and 10 ml. of 0.4 N NaOH was added and allowed to stand at room temperature for 5 to 10 minutes before reading the sample. Samples were then transferred to a 10-mm. rectangular silica cell and read at 470 mμ against distilled water as the reference liquid in a spectrophotometer and the per cent transmittance (%T) recorded. Lactic dehydrogenase activity was reported in LDH units per milliliter of serum of synovial fluid as determined by a standardization curve. Each LDH unit is equivalent to that amount of enzyme that would cause a decrease in O.D. at 340 mμ of 0.001/minute in a reaction mixture of a 3.0 ml. volume as established by Wröblewski and LaDue (1955).

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*Sigma Chemical Company, Inc., St. Louis, Mo.

Serum and Synovial Fluid Glutamic Oxalacetic and Glutamic Pyruvic Transaminase Activities

Serum and synovial fluid glutamic oxalacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) activities were determined by a micromethod as described by Reitman and Frankel (1957), employing 0.2 ml. quantities of the respective fluids. Samples for serum and synovial fluid GOT determinations were incubated at 38 C. for 60 minutes in 1.0 ml. quantities of an aspartate-a-ketoglutarate* substrate (buffered to pH 7.5). Samples for serum and synovial fluid GPT activity were incubated at 38 C. for 30 minutes in 1.0 ml. quantities of an alanine-a-ketoglutarate* substrate (buffered to pH 7.5). The reaction for both serum and synovial fluid GOT and GPT activity was stopped at the end of the incubation period by the addition of 1.0 ml. of 2,4-dinitrophenylhydrazine HCl.* Color was allowed to develop at room temperature for 20 minutes, after which 10 ml. of 0.4 N NaOH were added. Samples were allowed to stand for 5 to 10 minutes at room temperature and then transferred to a 10-mm. rectangular silica cell and read at 505 mμ against double-distilled water as a reference in a spectrophotometer at 25 C. The per cent transmittance (%T) was recorded and serum and synovial fluid GOT and GPT activity determined by a standardization curve and expressed in Sigma-Frankel (S-F)

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*Sigma Chemical Company, Inc., St. Louis, Mo.

units per milliliter. One Sigma-Frankel unit of GOT or GPT will form 4.82 x 10^{-4} μM of glutamate per minute at pH 7.5 at 25 C.

Cytologic Studies

Total erythrocyte and leukocyte counts were made from a noncentrifuged portion of the synovial fluid. For total erythrocyte and leukocyte counts, the synovial fluid was diluted 1:10 or 1:20 in a standard white blood-cell pipette with a 1% methyl violet-sodium chloride solution as described by Van Pelt (1962d). Synovial fluid that was serosanguineous or hemorrhagic in nature was diluted in a standard red blood-cell pipette 1:100 or 1:200. Leukocytes and erythrocytes were then counted in succession in the same counting chamber of a standard hemacytometer (improved Neubauer ruling). Differential leukocyte counts were made from stained smears of the sediment after centrifugation of the synovial fluid. Smears were made on glass microslides (25 by 75 mm.) previously cleaned with absolute methanol (acetone-free), air-dried, and stained with Wright's stain* for 1 minute. Phosphate buffer (.045 M at pH 6.33) was then added for 4 minutes, the slide then rinsed with double-distilled water, placed on end and air-dried. One hundred leukocytes were identified as described by Van Pelt and

*Gradwohl Laboratories, St. Louis, Mo.

Conner (1963a), and counted, and the absolute number of the various cell types determined for each sample of synovial fluid. These cell types included: (1) polymorphonuclear neutrophils; (2) lymphocytes; (3) monocytes; (4) macrophages; and (5) eosinophils. Synovial lining cells and degenerated leukocytes were occasionally seen but never included in either the total or differential leukocyte counts.

Bacteriologic Studies

Synovial fluid specimens intended for bacteriologic examination were transferred immediately from the aspirating syringe to sterile vials. Isolation and identification of microorganisms in septic synovial fluids were made by the Diagnostic Laboratory, Department of Microbiology and Public Health, College of Veterinary Medicine, Michigan State University.

Gross and Histopathologic Studies

Synovial tissue specimens were obtained by joint punch-biopsy as described by Van Pelt (1962c) and at necropsy from the various perimeters of the synovial membrane of 76 joints of 32 cattle and fixed immediately in 10% buffered neutral formalin for a minimum of 24 hours. Specimens of articular cartilage and subchondral bone were fixed as for synovium, decalcified,* and washed in running tap water for 2 hours prior to further tissue processing. Gross observations were made of the joint structures and other body organs at necropsy. Where indicated to establish disease processes other than that confined to the joint or joints, representative tissues were collected for histopathologic examination and processed accordingly. Where indicated, specimens for bacteriologic examination were taken from the joints and other body organs.

Sections of joint tissue were cut at 6 microns and stained according to the following procedures as outlined in the Armed Forces Institute of Pathology Manual of Histologic and Special Staining Technics (1960): (1) Harris' hematoxylin and eosin Y (H & E); (2) periodic acid-Schiff (PAS) reaction and counterstained with Harris' hematoxylin or light green solution; and (3) Von Kossa's method for

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*Decal, Omega Chemical Company, Garden City, N.Y.

demonstrating calcium, counterstained with nuclear fast red.

The joint capsule was divided into two strata according to the work of Trautmann and Fiebiger (1957). A *stratum fibrosum*, made up of dense fibrous tissue immediately blended with the ligamentous structures of the joint and a *stratum synoviale* (synovial membrane or synovium) which formed the lining of the joint cavity itself.

The *stratum synoviale* was classified on the basis of the predominant structure of the subintimal connective tissue as described by Castor (1960): (1) fibrous; (2) fibro-areolar; (3) areolar; (4) areolo-adipose; and (5) adipose.

In the course of histopathologic observations and descriptions, the articular cartilages were divided into four strata based on the work of Barnett *et al*. (1961). From the articular surface to the subchondral bone, these strata are: (1) the *stratum superficialis*; (2) the *stratum intermedius*; (3) the *stratum radiatus*; and (4) the cartilaginous *stratum calcificatum*.

IV. RESULTS

Synovial Fluid Analyses

Group I--Synovial Effusions that Resemble Normal Synovial Fluids

Degenerative Joint Disease

The joints of 29 cattle (Table 2) of various breeds, ranging in age from 1.5 years to 14 years, with a mean age of 7.4 $\pm$ 0.8 years, were investigated. Nine of the animals were bulls and 20 were cows. The tibiotarsal joint was most frequently affected, accounting for 76.5% of all joints investigated in this study. Joints of 2 of the animals were sampled twice. Primary degenerative joint disease accounted for 68% of all affected joints.

Total volume and gross appearance of the synovial effusions were observed and recorded for each joint (Table 3) at the time of arthrocentesis. An excessive synovial effusion was not considered pathognomonic of either primary or secondary degenerative joint disease; however, the gross appearance of the effusion as denoted by variable amounts of flocculent material was considered indicative of the degenerative processes taking place in affected joints.

TABLE 2. Incidence and Pathologic Classification of Synovial Effusions from the Joints of Cattle Affected with Degenerative Joint Disease

No.	Breed	Age (yr.)	Sex	Joint(s)	Classification*
1	Holstein-Friesian	14.0	Bull	Right Intercarpal	Primary
				Left Intercarpal	Primary
				Left Tibiotarsal	Primary
2	Aberdeen-Angus	6.0	Bull	Right Tibiotarsal	Primary
3	Holstein-Friesian	4.0	Cow	Right Tibiotarsal	Secondary
4	Holstein-Friesian	10.0	Cow	Left Tibiotarsal	Secondary
5	Holstein-Friesian	6.5	Bull	Left Tibiotarsal	Primary
				Right Tibiotarsal	Primary
6	Shorthorn	5.0	Bull	Left Femoropatellar	Primary
				Right Femoropatellar	Primary
				Left Tibiotarsal	Primary
				Right Tibiotarsal	Primary
7	Holstein-Friesian	2.5	Cow	Left Radiocarpal	Primary
				Right Radiocarpal	Primary
				Left Tibiotarsal	Primary
8	Guernsey	12.0	Bull	Left Tibiotarsal	Primary
				Right Tibiotarsal	Primary
9	Aberdeen-Angus	8.0	Bull	Left Tibiotarsal	Secondary
				Right Tibiotarsal	Secondary
10	Holstein-Friesian	12.0	Cow	Right Tibiotarsal	Primary
11	Holstein-Friesian	12.0	Cow	Right Tibiotarsal	Primary
12	Holstein-Friesian	14.0	Cow	Right Tibiotarsal	Primary
13	Holstein-Friesian	15.0	Cow	Right Tibiotarsal	Primary
14	Holstein-Friesian	3.5	Cow	Left Tibiotarsal	Secondary
15	Holstein-Friesian	3.0	Cow	Right Tibiotarsal	Secondary

*Pathologic joint effusions classified as follows: (1) primary = those associated with aging processes and ordinary usage; and (2) secondary = those due to joint conformation abnormalities and excessive microtrauma.

TABLE 2--Continued

No.	Breed	Age (yr.)	Sex	Joint(s)	Classification
16	Shorthorn	1.5	Bull	Right Metacarpophalangeal	Secondary
17	Holstein-Friesian	9.0	Bull	Left Tibiotarsal	Primary
				Right Tibiotarsal	Primary
18	Holstein-Friesian	5.5	Cow	Right Tibiotarsal	Secondary
19	Guernsey	6.0	Cow	Left Metatarsophalangeal	Secondary
20	Guernsey	5.0	Cow	Left Tibiotarsal	Primary
				Right Tibiotarsal	Primary
21	Holstein-Friesian	8.0	Cow	Right Tibiotarsal	Primary
22	Holstein-Friesian	6.0	Cow	Left Tibiotarsal	Primary
23	Holstein-Friesian	16.0	Cow	Right Tibiotarsal	Primary
24	Holstein-Friesian	4.25	Cow	Left Tibiotarsal	Secondary
				Right Tibiotarsal	Secondary
25	Holstein-Friesian	8.0	Cow	Left Tibiotarsal	Primary
				Right Tibiotarsal	Primary
26	Aberdeen-Angus	8.0	Bull	Right Radiocarpal	Primary
				Right Intercarpal	Primary
				Right Metacarpophalangeal	Secondary
27	Holstein-Friesian	3.17	Cow	Right Tibiotarsal	Secondary
28	Holstein-Friesian	4.0	Cow	Left Tibiotarsal	Secondary
				Right Tibiotarsal	Secondary
29	Jersey	4.0	Cow	Left Tibiotarsal	Primary
				Right Tibiotarsal	Primary

TABLE 3. Total Volume and Gross Appearance of Synovial Fluid Obtained from the Joints of Cattle Affected with Degenerative Joint Disease

Joints	No.	Total Volume (cc./joint) Range	Mean	Gross Appearance* N	NF	NOF	YOF	AF	AOF	TYF
Radiocarpal	3	2.0 to 9.5	5.50 ± 2.17**	0	0	2	1	0	0	0
Intercarpal	3	8.5 to 9.5	9.00 ± 0.29	2	0	0	1	0	0	0
Metacarpophalangeal	2	1.0 to 5.5	3.25 ± 2.26	0	0	1	0	0	0	1
Femoropatellar	2	3.0 to 10.0	6.50 ± 3.50	0	0	2	0	0	0	0
Tibiotarsal	36	3.5 to 45.0	15.67 ± 1.66	12	1	11	2	1	9	0
Metatarsophalangeal	1	2.25 to 0.0	2.25 ± 0.00	0	0	0	0	0	1	0

*Gross appearance of the synovial fluid: N = normal (colorless and clear); NF = colorless and clear, with some flocculent material; NOF = colorless and opaque, with some flocculent material; YOF = pale yellow and opaque, with some flocculent material; AF = amber and clear, with some flocculent material; AOF = amber and opaque, with some flocculent material; and TYF = turbid and yellow, with some flocculent material.

**Standard error of the mean.

The relative viscosity of the synovial fluid as determined by its rheologic behavior and quality of mucinous precipitate (Table 4) was highest for the smaller joints. In only one instance was there an insufficient quantity of synovial fluid for determination of its relative viscosity.

A mean synovial fluid sugar value of 62.83 ± 3.17 mg./100 ml. for all joints affected with degenerative joint disease did not differ significantly from the mean corresponding blood sugar level of 63.50 ± 3.18 mg./100 ml., thus maintaining an approximate 1:1 ratio. Synovial fluid sugar values for the tibiotarsal joint were of sufficient number to permit statistical analysis; however, the mean sugar levels for this joint did not differ significantly from its corresponding mean blood sugar level (Table 5). The number of synovial fluid and blood sugar determinations for the other joints were considered too small to permit statistical analysis.

There was a total mean alkaline phosphatase (ALP) value of 2.80 ± 0.62 Sigma units/ml. of synovial fluid for all joints affected with degenerative joint disease. This value was significantly ($P = 0.001$) greater than the mean value of 1.46 ± 0.28 Sigma units/ml. for serum from these animals. The mean value for synovial fluid ALP activity for the tibiotarsal joint also was significantly ($P = 0.001$) greater than the corresponding value obtained for serum ALP

TABLE 4. Relative Viscosity and Mucinous Precipitate Quality of Synovial Fluid from the Joints of Cattle Affected with Degenerative Joint Disease

Joints	Relative Viscosity*			Mucinous Precipitate Quality**				
	No.	Range	Mean	No.	N	F	P	VP
Radiocarpal	2	3.05 to 86.92	44.99 ± 42.06***	3	2	1	0	0
Intercarpal	3	9.43 to 111.84	55.39 ± 30.08	3	3	0	0	0
Metacarpophalangeal	1	0	30.62 ± 0.0	1	0	1	0	0
Femoropatellar	2	2.20 to 7.68	4.94 ± 3.17	2	0	1	1	0
Tibiotarsal	36	1.36 to 8.84	3.42 ± 0.30	36	22	11	3	0
Metatarsophalangeal	1	QNS****	QNS	1	1	0	0	0

*Relative viscosity determinations were made at 38.6 C.

**Mucinous precipitate quality graded: N = normal; F = fair; P = poor; and VP = very poor.

***Standard error of the mean.

****QNS = quantity nonsufficient for a determination.

TABLE 5. A Comparison of Synovial Fluid and Blood Sugar Values for Cattle Affected with Degenerative Joint Disease

Joints	No. of Joint Samples*	Mg. Synovial Sugar/100 ml. Range	Mg. Synovial Sugar/100 ml. Mean	No. of Blood Samples	Mg. Blood Sugar/100 ml. Range	Mg. Blood Sugar/100 ml. Mean
Radiocarpal	3	34 to 90	53.33 ± 18.22**	2	53 to 70	61.25 ± 8.54
Intercarpal	3	38 to 57	50.00 ± 6.04	2	53 to 68	60.50 ± 7.50
Metacarpophalangeal	2	59 to 100	79.50 ± 19.86	2	53 to 55	54.00 ± 0.00
Femoropatellar	2	33 to 89	61.00 ± 28.07	1	0	94.00 ± 0.00
Tibiotarsal	36	16 to 122	64.22 ± 3.52***	30	38 to 106	63.53 ± 3.39
Metatarsophalangeal	1	0	50.00 ± 0.00	1	0	70.00 ± 0.00
Total Values	47	16 to 122	62.83 ± 3.17***	38	38 to 106	63.50 ± 3.18

*For each animal, synovial fluid and blood sugar values were determined.

**Standard error of the mean.

***No statistically significant difference was encountered between synovial fluid and blood sugar values.

activity (Table 6). With the exception of one sample each from the intercarpal, femoropatellar, and metatarsophalangeal joints, mean synovial fluid ALP activity for the remaining joints proved to be higher than its corresponding serum ALP activity.

The mean synovial fluid lactic dehydrogenase (LDH) activity of 228 ± 116 LDH units/ml. for all joints affected with degenerative joint disease was significantly ($P = 0.001$) lower than its mean corresponding serum LDH activity of 1887 ± 169 LDH units/ml. Synovial fluid LDH activity (Table 7) for the various joints investigated was considerably lower in all cases than the corresponding values obtained for serum. Synovial effusions from the tibiotarsal joint were in sufficient number to permit comparison with their corresponding serum values. The mean serum LDH activity was significantly ($P = 0.001$) greater than the mean synovial fluid LDH activity for the tibiotarsal joint (Table 7).

The mean synovial fluid glutamic oxalacetic transaminase (SY-GOT) activity of 21.65 ± 5.17 Sigma-Frankel units/ml. for all joints affected with degenerative joint disease proved to be significantly ($P = 0.001$) lower in comparison to the mean serum glutamic oxalacetic transaminase (S-GOT) activity of 59.84 ± 7.90 Sigma-Frankel units/ml. (Table 8). Likewise, the mean synovial fluid glutamic pyruvic transaminase (SY-GPT) activity of 10.96 ± 3.16

TABLE 6. A Comparison of Synovial Fluid and Serum Alkaline Phosphatase Activity Values for Cattle Affected with Degenerative Joint Disease

Joints	No. of Joint Samples*	Sigma Units/ml. of Synovial Fluid		No. of Serum Samples	Sigma Units/ml. of Serum	
		Range	Mean		Range	Mean
Radiocarpal	3	1.10 to 1.75	1.52 ± 0.21**	2	0.85 to 1.05	0.95 ± 0.00
Intercarpal	1	0	0.63 ± 0.00	1	0	0.85 ± 0.00
Metacarpo-phalangeal	2	0.75 to 2.10	1.43 ± 0.67	2	0.85 to 1.47	1.16 ± 0.31
Femoropatellar	2	0.50 to 0.80	0.65 ± 0.02	1	0	2.95 ± 0.00
Tibiotarsal	33	0.03 to 23.95	3.28 ± 0.77***	26	0.30 to 7.35	1.52 ± 0.31
Metatarso-phalangeal	1	0	0.15 ± 0.00	1	0	0.70 ± 0.00
Total Values	42	0.03 to 23.95	2.80 ± 0.62***	33	0.30 to 7.35	1.46 ± 0.28

*For each animal, synovial fluid and serum alkaline phosphatase activity values were determined.

**Standard error of the mean.

***Significantly (P = 0.001) greater than the corresponding serum value.

TABLE 7. A Comparison of Synovial Fluid and Serum Lactic Dehydrogenase Activity Values for Cattle Affected with Degenerative Joint Disease

Joints	No. of Joint Samples*	LDH Units/ml. of Synovial Fluid		No. of Serum Samples	LDH Units/ml. of Serum	
		Range	Mean		Range	Mean
Radiocarpal	1	0	205 ± 0	1	0	1340 ± 0
Intercarpal	1	0	213 ± 0	1	0	1340 ± 0
Metacarpo-phalangeal	2	290 to 383	337 ± 1**	2	1340 to 2140	1740 ± 126
Tibiotarsal	20	43 to 560	213 ± 28***	15	397 to 3250	1651 ± 248
Metatarso-phalangeal	1	0	367 ± 0	1	0	1950 ± 0
Total Values	25	43 to 560	228 ± 116***	20	397 to 3250	1887 ± 169

*For each animal, synovial fluid and serum lactic dehydrogenase activity values were determined.

**Standard error of the mean.

***Significantly (P = 0.001) less than the corresponding serum value.

TABLE 8. A Comparison of Synovial Fluid and Serum Glutamic Oxalacetic Transaminase Activity Values for Cattle Affected with Degenerative Joint Disease

Joints	No. of Joint Samples*	Sigma-Frankel Units/ml. of Synovial Fluid		No. of Serum Samples	Sigma-Frankel Units/ml. of Serum	
		Range	Mean		Range	Mean
Radiocarpal	1	0	4.00 ± 0.00	1	0	33.00 ± 0.00
Intercarpal	1	0	3.00 ± 0.00	1	0	33.00 ± 0.00
Metacarpo-phalangeal	2	19 to 48	33.50 ± 14.53**	2	33 to 51	42.00 ± 9.03
Tibiotarsal	21	0 to 45	16.76 ± 2.30***	16	11 to 115	65.81 ± 8.27
Metatarso-phalangeal	1	0	0.00 ± 0.00	1	0	137.00 ± 0.00
Total Values	26	0 to 48	21.65 ± 5.17***	21	11 to 115	59.84 ± 7.90

*For each animal, synovial fluid and serum glutamic oxalacetic transaminase activity values were determined.

**Standard error of the mean.

***Significantly (P = 0.001) less than the corresponding serum value.

Sigma-Frankel units/ml. proved to be significantly (P = 0.001) lower when compared to its respective mean serum glutamic pyruvic transaminase (S-GPT) activity of 21.21 ± 7.35 Sigma-Frankel units/ml. (Table 9). The data obtained for synovial effusions and sera (Table 8 and 9) revealed lower values for all joints in relation to their respective serum values, with one exception, a SY-GPT value higher than the S-GPT value was obtained for the metatarsophalangeal joint of one animal (Table 9). Mean SY-GOT and S-GPT values for the tibiotarsal joint were found to be significantly (P = 0.001) lower when compared to their corresponding mean S-GOT and S-GPT values.

Total erythrocyte and leukocyte values for the various joints (Table 10) followed no consistent pattern for the various joints investigated. Although the synovial fluid specimens utilized were not grossly hemorrhagic, elevated erythrocyte counts in some specimens were attributed to struggling on the part of the animal at the time of arthrocentesis. When the absolute number of the various synovial fluid leukocytes was determined, lymphocytes and monocytes proved to be the predominant cell type (Table 11). The presence of neutrophils was not a consistent feature and eosinophils, with the exception of data collected from the tibiotarsal joints, proved to be non-existent in synovial effusions obtained from joints affected with degenerative joint disease.

TABLE 9. A Comparison of Synovial Fluid and Serum Glutamic Pyruvic Transaminase Activity Values for Cattle Affected with Degenerative Joint Disease

Joints	No. of Joint Samples*	Sigma-Frankel Units/ml. of Synovial Fluid		No. of Serum Samples	Sigma-Frankel Units/ml. of Serum	
		Range	Mean		Range	Mean
Radiocarpal	1	0	2.00 ± 0.00	1	0	8.00 ± 0.00
Intercarpal	1	0	5.00 ± 0.00	1	0	8.00 ± 0.00
Metacarpo-phalangeal	2	6 to 10	8.00 ± 2.01**	2	8 to 25	16.50 ± 8.51
Tibiotarsal	21	0 to 75	10.18 ± 3.47***	16	0 to 145	21.63 ± 8.73
Metatarso-phalangeal	1	0	47.00 ± 0.00	1	0	23.00 ± 0.00
Total Values	26	0 to 75	10.96 ± 3.16***	21	0 to 145	21.21 ± 7.35

*For each animal, synovial fluid and serum glutamic pyruvic transaminase activity values were determined.

**Standard error of the mean.

***Significantly (P = 0.001) less than corresponding serum value.

TABLE 10. Total Numbers of Erythrocytes and Leukocytes for Synovial Fluid from Cattle Affected with Degenerative Joint Disease

Joints	No.	RBC x 10^3/cmm.	No.	WBC/cmm.
Radiocarpal	3	33.07 ± 2.20*	3	646.33 ± 233.16
		(0.22 - 97.60)**		(189 - 950)
Intercarpal	3	0.01 ± 0.01	3	98.00 ± 68.51
		(0.00 - 0.02)		(11 - 233
Metacarpophalangeal	2	37.72 ± 35.37	2	1316.50 ± 201.50
		(2.44 - 73.00)		(1033 - 1600)
Femoropatellar	2	2.88 ± 2.65	2	466.50 ± 334.53
		(0.20 - 5.55)		(133 - 800)
Tibiotarsal	36	19.83 ± 9.86	36	328.14 ± 93.17
		(0.00 - 245.00)		(10 - 2725)
Metatarsophalangeal	1	30.45 ± 0.00	1	478.00 ± 0.00
		(0)		(0)

*Standard error of the mean.

**Range of values for the respective joints.

TABLE 11. Absolute Numbers of Various Leukocytes in Synovial Fluid from Cattle Affected with Degenerative Joint Disease

Joints	No.	Absolute Numbers of Leukocytes/cmm. Neutrophils	Lymphocytes	Monocytes	Macrophages	Eosinophils
Radio-carpal	3	130.86 ± 65.66* (41.58 - 256.00)**	271.25 ± 101.14 (124.74 - 465.50)	227.33 ± 115.10 (0.00 - 370.50)	13.39 ± 4.73 (8.00 - 22.68)	0.00 ± 0.00 (0.00 - 0.00)
Inter-carpal	3	0.20 ± 0.48 (0.00 - 0.50)	62.41 ± 55.21 (1.21 - 174.75)	22.89 ± 18.09 (3.41 - 58.25)	12.76 ± 9.86 (0.00 - 32.00)	0.00 ± 0.00 (0.00 - 0.00)
Metacarpo-phalangeal	2	29.17 ± 19.15 (10.33 - 48.00)	512.50 ± 273.19 (240.00 - 785.08)	385.50 ± 158.87 (227.26 - 544.00)	381.00 ± 373.05 (10.33 - 752.00)	0.00 ± 0.00 (0.00 - 0.00)
Tibio-tarsal	35	70.18 ± 53.11 (0.00-1872.00)	120.57 ± 42.38 (0.00-1389.75)	122.18 ± 41.65 (0.00-1280.75)	15.95 ± 7.06 (0.00 - 244.75)	1.21 ± 0.84 (0.00-27.25)
Femoro-patellar	2	74.65 ± 61.71 (13.30 - 136.00)	73.30 ± 46.45 (26.60 - 120.00)	318.55 ± 225.53 93.10 - 544.00)	0.00 ± 0.00 (0)	0.00 ± 0.00 (0)
Metatarso-phalangeal	1	76.48 ± 0.00 (0)	248.56 ± 0.00 (0)	114.46 ± 0.00 (0)	33.46 ± 0.00 (0)	4.78 ± 0.00 (0)

*Standard error of the mean.

**Range of values for the respective joints.

Traumatic Arthritis

The joints of 14 cattle (Table 12) of various breeds, ranging in age from 7 months to 8 years, with a mean age of 2.6 ± 0.6 years, were investigated. Three of the animals were bulls, 5 were cows, 5 were heifers, and 1 was a steer.

Classification of acute or chronic traumatic arthritis was based on: (1) anamnesis; (2) clinical examination; and (3) duration of the effusion. Traumatic arthritis was generally monarticular in nature; however, 7 of the animals were affected with polyarticular traumatic arthritis. Thirteen joints of 10 animals were classified as acute and 12 joints of 6 animals were classified as chronic traumatic arthritis. Two of the animals were affected simultaneously with an acute polyarthritis and chronic traumatic arthritis. The tibiotarsal joint was most frequently involved, accounting for 84.6% of the acute cases and 50% of the chronic cases.

Animals affected with acute traumatic arthritis generally had a history of direct trauma to the affected joint as a direct result of rough handling, postparturient hypocalcemia with subsequent injury when the animal was in the recumbent position, or trauma of an unknown source. Joints affected with chronic traumatic arthritis generally had a history of previous trauma to the joint or exposure to repeated and mild trauma over a prolonged period of time.

TABLE 12. Incidence and Pathologic Classification of Synovial Effusions from the Joints of Cattle Affected with Traumatic Arthritis

No.	Breed	Age	Sex	Joint(s)	Classification*
1	Holstein-Friesian	4.0 yrs.	Cow	Left Femoropatellar	Acute
				Left Tibiotarsal	Acute
2	Holstein-Friesian	2.0 yrs.	Heifer	Left Tibiotarsal	Chronic
				Right Tibiotarsal	Acute
3	Holstein-Friesian	7 mo.	Heifer	Right Tibiotarsal	Acute
4	Holstein-Friesian	1.75 yrs.	Bull	Left Tibiotarsal	Acute
5	Holstein-	3.0 yrs.	Cow	Left Radiocarpal	Chronic
				Right Radiocarpal	Chronic
				Left Intercarpal	Chronic
				Right Intercarpal	Chronic
				Left Tibiotarsal	Chronic
				Right Tibiotarsal	Chronic
6	Guernsey	1.5 yrs.	Bull	Left Metatarso-phalangeal	Chronic
7	Holstein-Friesian	8.0 yrs.	Cow	Left Tibiotarsal	Acute
8	Holstein-Friesian	6.0 yrs.	Cow	Right Tibiotarsal	Chronic
9	Aberdeen-Angus	1.0 yr.	Heifer	Left Tibiotarsal	Acute
				Right Tibiotarsal	Acute
10	Holstein-	5.0 yrs.	Cow	Left Tibiotarsal	Acute
				Right Tibiotarsal	Acute
11	Hereford	1.0 yr.	Steer	Left Tibiotarsal	Chronic
				Right Tibiotarsal	Chronic
12	Holstein-Friesian	7 mo.	Heifer	Left Radiocarpal	Acute
				Left Intercarpal	Chronic
13	Holstein-Friesian	2.0 yrs.	Bull	Left Tibiotarsal	Acute
14	Holstein-Friesian	8 mo.	Heifer	Left Tibiotarsal	Acute

*Traumatic joint effusions produced as a result of direct injury to the joint and classified as acute or chronic.

On clinical examination of cattle affected with acute traumatic arthritis there was generally marked evidence of distention of the joint capsules, localized pain, evidence of abrasions or contusions, reluctance to bear weight on the affected limb or limbs, and varying degrees of claudication. Joints affected with chronic traumatic arthritis appeared clinically similar to the acute cases, but, without the severity of gross lesions.

The total volume of synovial fluid obtained from the tibiotarsal joints of cattle affected with acute traumatic arthritis was significantly ($P = 0.001$) greater than that obtained from joints affected with chronic traumatic arthritis (Table 13). The smaller joints did not contain the excessive effusions as observed in the case of the tibiotarsal joints. All of the joints affected with acute traumatic arthritis contained synovial effusions that were either serosanguineous or hemorrhagic in nature (Table 14), whereas joints affected with chronic traumatic arthritis (Table 14) contained effusions that were predominantly amber in color (xanthochromic), indicative of their high bilirubin content due to prolonged intra-articular hemorrhage and subsequent erythrocyte destruction.

The relative viscosity of synovial effusions from acutely traumatized joints as determined by their rheologic behavior were slightly but not significantly higher than

TABLE 13. Total Volume of Synovial Fluid Obtained from the Joints of Cattle Affected with Acute or Chronic Traumatic Arthritis

Joints	No. of Joint Samples		Total Volume (cc./joint)	
	Acute	Chronic	Acute	Chronic
Radiocarpal	1	2	2.50 ± 0.00	4.38 ± 0.63*
			(0)	(3.75 - 5.00)**
Intercarpal	0	3	...	4.25 ± 0.82
				(3.25 - 5.50)
Femoropatellar	1	0	8.00 ± 0.00	...
			(0)	
Tibiotarsal	11	6	29.02 ± 9.83***	18.54 ± 6.56
			(5 - 100)	(6.5 - 50)
Metatarso-phalangeal	0	1	...	3.20 ± 0.00
				(0)

*Standard error of the mean.

**Range of values for the respective joints.

***Significantly (P = 0.001) greater than the corresponding volume obtained from joints affected with chronic traumatic arthritis.

TABLE 14. Gross Appearance of Synovial Fluid from the Joints of Cattle Affected with Acute or Chronic Traumatic Arthritis

Joints	No. of Joint Samples		Gross Appearance*							
			AO		AOF		SS		H	
	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic
Radiocarpal	1	2	0	0	0	1	1	1	0	0
Intercarpal	0	3	0	0	0	3	0	0	0	0
Femoropatellar	1	0	0	0	0	0	1	0	0	0
Tibiotarsal	11	6	0	3	0	3	6	0	5	0
Metatarso-phalangeal	0	1	0	0	0	1	0	0	0	0

*Gross appearance of the synovial fluid: AO = amber and opaque; AOF = amber and opaque, with some flocculent material; SS = serosanguineous; and H = hemorrhagic.

the corresponding values obtained for joints affected with chronic traumatic arthritis (Table 15). The mucinous precipitate in acutely traumatized joints was also of a better quality than that chronically traumatized joints. No statistically significant differences were determined for the relative viscosity of synovial effusions when a comparison was made between effusions from tibiotarsal joints affected with acute or chronic traumatic arthritis.

The mean sugar level was 75.54 $\pm$ 4.88 mg./100 ml. for all joints affected with acute traumatic arthritis. This value was significantly (P = 0.001) higher than the mean blood sugar level of 68.00 $\pm$ 3.76 mg./100 ml. obtained for cattle affected with acute traumatic arthritis. Cattle affected with chronic traumatic arthritis were found to have a mean synovial fluid sugar level of 57.92 $\pm$ 2.49 mg./100 ml. for all joints, which was significantly (P = 0.01) higher than their mean corresponding blood sugar level of 52.67 $\pm$ 4.98 mg./100 ml. When the mean synovial fluid and blood sugar levels for cattle affected with acute traumatic arthritis were compared with cattle affected with chronic traumatic arthritis, synovial fluid and blood sugar values for cattle with acute traumatic arthritis were found to be significantly (P = 0.001) higher. Synovial fluid sugar levels for the various types of joints analyzed, with the exception of one joint, were in excess of their corresponding blood sugar levels for both acute and chronic traumatic

TABLE 15. Relative Viscosity and Mucinous Precipitate Quality of Synovial Fluid from the Joints of Cattle Affected with Acute or Chronic Traumatic Arthritis

Joints	No. of Joint Samples		Relative Viscosity*		Mucinous Precipitate Quality**							
					N		F		P		VP	
	Acute	Chronic	Acute	Chronic	A$^{\phi}$	C$^{\phi}$	A$^{\phi}$	C$^{\phi}$	A$^{\phi}$	C$^{\phi}$	A$^{\phi}$	C$^{\phi}$
Radiocarpal	1	2	2.68 ± 0.00 ($\overline{0}$)	2.18 ± 0.29*** (1.89 - 2.47)****	0	0	0	0	0	0	1	2
Intercarpal	0	3	...	3.87 ± 1.29 (2.47 - 6.45)	0	0	0	3	0	0	0	0
Femoropatellar	1	0	2.90 ± 0.00 ($\overline{0}$)	...	1	0	0	0	0	0	0	0
Tibiotarsal	11	6	3.75 ± 0.60 (1.53 - 8.09)	2.63 ± 0.46 (1.37 - 4.07)	2	0	6	4	3	2	0	0
Metatarso-phalangeal	0	1	...	7.24 ± 0.00 ($\overline{0}$)	0	0	0	1	0	0	0	0

$^{\phi}$A = acute; C = chronic.

*Relative viscosity determinations were made at 38.6 C.

**Mucinous precipitate quality graded: N = normal; F = fair; P = poor; and VP = very poor.

***Standard error of the mean.

****Range of values for the respective joints.

arthritis (Table 16). The sugar level of one metatarsophalangeal joint affected with chronic traumatic arthritis was 3 mg./100 ml. less than its corresponding blood sugar level. The mean synovial fluid sugar value for acute traumatic arthritis of the tibiotarsal joint was significantly ($P = 0.001$) higher than its corresponding mean blood sugar value. The mean synovial fluid sugar value for synovial fluid from tibiotarsal joints affected with chronic traumatic arthritis was also significantly ($P = 0.05$) higher than its mean corresponding blood sugar value. A comparison of the mean synovial fluid and blood sugar levels for cattle affected with acute traumatic arthritis of the tibiotarsal joint was found to be significantly ($P = 0.001$) higher than the corresponding mean value for cattle affected with chronic traumatic arthritis of the tibiotarsal joint.

There was no statistically significant difference between the mean synovial fluid alkaline phosphatase (ALP) activity for tibiotarsal joints affected with acute traumatic arthritis and their corresponding mean serum alkaline phosphatase (ALP) activity (Table 17). The mean synovial fluid ALP activity for chronically traumatized tibiotarsal joints was significantly ($P = 0.05$) higher than its mean corresponding serum ALP activity. A mean ALP activity of 3.24 ± 0.71 Sigma units/ml. was obtained for synovial effusions from all acutely traumatized joints. This value proved to be significantly ($P = 0.05$) higher than the mean

TABLE 16.—A Comparison of Synovial Fluid and Blood Sugar Values for Cattle Affected with

TABLE 16. A Comparison of Synovial Fluid and Blood Sugar Values for Cattle Affected with Acute or Chronic Traumatic Arthritis

Joints	No. of Joint Samples* Acute	Chronic	Mg. Synovial Sugar/100 ml. Acute	Chronic	No. of Blood Samples Acute	Chronic	Mg. Blood Sugar/100 ml. Acute	Chronic
Radiocarpal	1	2	45.00 ± 0.00 (0)	59.50 ± 4.49** (55 - 64)***	1	1	36.00 ± 0.00 (0)	59.00 ± 0.00 (0)
Intercarpal	0	3	....	53.00 ± 3.01 (50 - 59)	0	2	....	47.50 ± 11.52 (36 - 59)
Femoro-patellar	1	0	73.00 ± 0.00 (0)	....	1	0	68.00 ± 0.00 (0)	....
Tibiotarsal	11	6	78.55 ± 4.64a (55 - 100)	58.67 ± 4.43c (39 - 68)	9	4	71.56 ± 2.43 (68 - 83)	53.00 ± 4.38 (42 - 61)
Metatarso-phalangeal	0	1	....	65.00 ± 0.00	0	1	....	68.00 ± 0.00
Total Values	13	12	75.54 ± 4.88a (45 - 100)	57.92 ± 2.49 (39 - 68)	11	8	68.00 ± 3.76b (36 - 83)	52.67 ± 4.98 (42 - 68)

*For each animal, synovial fluid and blood sugar values were determined.

**Standard error of the mean.

***Range of values for the respective joints and blood determinations.

[a]Significantly (P = 0.001) greater than corresponding blood value.

[b]Significantly (P = 0.01) greater than corresponding value for cattle affected with chronic traumatic arthritis.

[c]Significantly (P = 0.05) greater than corresponding blood value.

TABLE 17. A Comparison of Synovial Fluid and Serum Alkaline Phosphatase Activity Values for Cattle Affected with Acute or Chronic Traumatic Arthritis

Joints	No. of Joint Samples* Acute	Chronic	Sigma Units/ml. of Synovial Fluid Acute	Chronic	No. of Serum Samples Acute	Chronic	Sigma Units/ml. of Serum Acute	Chronic
Radiocarpal	1	2	3.70 ± 0.00 ($\overline{0}$)	2.95 ± 0.45** (2.50 - 3.40)***	1	1	1.90 ± 0.00 ($\overline{0}$)	2.70 ± 0.00 ($\overline{0}$)
Intercarpal	0	2	...	2.47 ± 0.20 (0)	0	1	...	2.70 ± 0.00 ($\overline{0}$)
Tibiotarsal	10	6	3.19 ± 0.78a (0.35 - 6.45)	4.01 ± 2.08c (0.43 - 11.22)	8	4	2.12 ± 0.35 (0.75 - 3.80)	1.58 ± 0.53 (0.63 - 2.70)
Metatarso-phalangeal	0	1	...	4.75 ± 0.00	0	1	...	2.05 ± 0.00
Total Values	11	11	3.24 ± 0.71c (0.35 - 6.45)	3.62 ± 1.02b (0.43 - 11.22)	9	7	2.09 ± 0.31b (0.75 - 3.80)	1.71 ± 0.34 (0.63 - 2.70)

*For each animal, synovial fluid and serum alkaline phosphatase activity values were determined.

**Standard error of the mean.

***Range of values for the respective joints and sera.

[a]No statistically significant difference between synovial fluid and serum.

[b]Significantly (P = 0.01) greater than the corresponding serum value.

[c]Significantly (P = 0.05) greater than the corresponding serum value.

serum ALP activity of 2.09 ± 0.31 Sigma units/ml. obtained for the serum from these animals. Synovial effusions from all chronically traumatized joints had a mean ALP activity of 3.62 ± 1.02 Sigma units/ml. that proved to be significantly ($P = 0.01$) higher than the value of 1.71 ± 0.34 Sigma units/ml. of serum obtained from these animals. No statistically significant differences were encountered when a comparison was made between synovial effusions and sera from cattle affected with acute traumatic arthritis and those from cattle affected with chronic traumatic arthritis.

The mean number of erythrocytes (197.53 ± 2.71 x 10^3/cmm.) and leukocytes (3129.27 ± 1692.37/cmm.) for synovial fluid from the tibiotarsal joints affected with acute traumatic arthritis was significantly ($P = 0.001$) greater than the number of erythrocytes (8.11 ± 4.76 x 10^3/cmm.) and leukocytes (979.33 ± 588.50/cmm.) recorded for tibiotarsal joints affected with chronic traumatic arthritis (Table 18). Determination of the absolute number of various synovial fluid leukocytes revealed a greater number of neutrophils and lymphocytes per cubic millimeter in synovial effusions from acutely traumatized joints (Table 19) in contrast to the findings for joints chronically traumatized (Table 20). The total number of monocytes proved to be proportionally higher in the chronic synovial effusions.

TABLE 18. Total Numbers of Erythrocytes and Leukocytes for Synovial Fluid from Cattle Affected with Acute or Chronic Traumatic Arthritis

Joints	No. of Joint Samples		RBC x 10^3/cmm.		WBC/cmm.	
	Acute	Chronic	Acute	Chronic	Acute	Chronic
Radiocarpal	1	2	270.00 ± 0.00 ($\bar{0}$)	24.39 ± 19.66* (4.78 - 44.00)**	512.00 ± 0.00 ($\bar{0}$)	50.00 ± 28.08 (33 - 78)
Intercarpal	0	3	...	10.94 ± 4.41 (2.83 - 12.00)	...	672.00 ± 92.00 (11 - 1912)
Femoro-patellar	1	0	3.60 ± 0.00 ($\bar{0}$)	...	144.00 ± 0.00 ($\bar{0}$)	...
Tibiotarsal	11-	6	197.53 ± 2.71*** (1.33 - 655.00)	8.11 ± 4.76 (0.67 - 20.30)	3129.26 ± 1692.37*** (44 - 12556)	979.33 ± 588.50 (22 - 3833)
Metatarso-phalangeal	0	1	...	1700.00 ± 0.00 ($\bar{0}$)	...	911.00 ± 0.00 ($\bar{0}$)

*Standard error of the mean.

**Range of values for the respective joints.

***Significantly (P = 0.001) greater than the corresponding value obtained for joints affected with chronic traumatic arthritis.

TABLE 19. Absolute Numbers of Various Leukocytes for Synovial Fluid from Cattle Affected with Acute Traumatic Arthritis

Joints	No.	Absolute Number of Leukocytes/cmm. Neutrophils	Lymphocytes	Monocytes	Macrophages	Eosinophils
Radiocarpal	1	153.00 ± 0.00 ($\bar{0}$)	102.40 ± 0.00 ($\bar{0}$)	204.80 ± 0.00 ($\bar{0}$)	51.20 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)
Femoropatellar	1	2.88 ± 0.00 ($\bar{0}$)	21.60 ± 0.00 ($\bar{0}$)	96.48 ± 0.00 ($\bar{0}$)	23.04 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)
Tibiotarsal	11	821.60 ± 378.31 (0 - 337.82)	2022.73 ± 1096.00 (2.64 - 4888.95)	271.59 ± 97.93 (7.90 - 994.56)	10.22 ± 5.86 (0 - 66.00)	3.16 ± 2.98* (0 - 33.00)

*Standard error of the mean.

**Range of values for the respective joints.

TABLE 20. Absolute Numbers of Various Leukocytes for Synovial Fluid from Cattle Affected with Chronic Traumatic Arthritis

Joints	No.	Absolute Numbers of Leukocytes/cmm. Neutrophils	Lymphocytes	Monocytes	Macrophages	Eosinophils
Radiocarpal	2	0.00 ± 0.00 ($\bar{0}$)	17.80 ± 13.44 (4.40 – 31.20)	22.20 ± 9.02 (13.20 – 31.20)	10.00 ± 5.62* (4.40 – 15.60)**	0.00 ± 0.00 ($\bar{0}$)
Intercarpal	3	388.77 ± 388.77 (0 – 1166.32)	5.13 ± 4.05 (0 – 13.20)	253.69 ± 245.92 (2.20 – 745.68)	4.40 ± 2.20 (0 – 6.60)	0.00 ± 0.00 ($\bar{0}$)
Tibiotarsal	6	40.55 ± 7.10 (0 – 114.96)	745.34 ± 176.89 (2.31 – 3564.69)	164.77 ± 26.57 (4.40 – 568.96)	29.26 ± 10.84 (0 – 73.22)	0.00 ± 0.00 ($\bar{0}$)
Metatarso-phalangeal	1	18.22 ± 0.00 ($\bar{0}$)	81.99 ± 0.00 ($\bar{0}$)	373.51 ± 0.00 ($\bar{0}$)	437.28 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)

*Standard error of the mean.

**Range of values for the respective joints.

Hydrarthrosis

Ten tibiotarsal joints of 8 cattle (Table 21) affected with acute, subacute, or chronic hydrarthrosis were investigated. These animals ranged in age from 1.5 years to 8 years, with a mean age of 3.0 $\pm$ 0.8 years. Five of the animals were bulls and 3 were cows.

During the course of this investigation, hydrarthrosis in cattle was observed to be limited to the tibiotarsal joint and the proximal intertarsal joint. Its occurrence in the latter joint was attributed to its posterior communication with the tibiotarsal joint as described by Van Pelt (1962b). This condition was characterized clinically by a pronounced distention of the tibiotarsal synovial sacs (dorsomedial cul-de-sac, medioplantar, and lateroplantar pouches), and the dorsomedial pouch of the proximal intertarsal synovial sac. None of the joints examined revealed evidence of local inflammation and signs of claudication were never observed. Anamnesis established the fact that the condition was generally idiopathic and insidious in nature, with periods of remission and exacerbation. With the exception of one 8-year-old Holstein-Friesian bull, all other animals were 3 years of age or under. All animals were confined to limited quarters, with little or no exercise. Arthrocentesis of the tibiotarsal joint revealed excessive synovial effusion, under considerable pressure, and colorless in 90% of the joints investigated.

TABLE 21. Incidence and Pathologic Classification of Synovial Effusions from the Joints of Cattle Affected with Tarsal Hydrarthrosis

No.	Breed	Age (yr.)	Sex	Joint(s)	Classification*
1	Holstein-Friesian	3.00	Cow	Left Tibiotarsal Right Tibiotarsal	Chronic Chronic
2	Holstein-Friesian	1.75	Heifer	Right Tibiotarsal	Chronic
3	Holstein-Friesian	2.33	Bull	Right Tibiotarsal	Chronic
4	Hereford	1.50	Heifer	Right Tibiotarsal	Chronic
5	Holstein-Friesian	8.00	Bull	Left Tibiotarsal Right Tibiotarsal	Acute Acute
6	Holstein-Friesian	1.50	Bull	Left Tibiotarsal	Chronic
7	Holstein-Friesian	3.00	Bull	Left Tibiotarsal	Subacute
8	Holstein-Friesian	2.50	Bull	Left Tibiotarsal	Subacute

*Classified on the basis of history, clinical examination, and synovial fluid analyses as acute, subacute, or chronic.

Marked elevations in intra-articular pressure were a consistent feature of tarsal hydrarthrosis.

The relative viscosity of the synovial effusions was markedly reduced (Table 22); however, 60% of the joints contained synovial effusions with a normal mucinous precipitate quality.

No statistically significant differences were found when a comparison was made between synovial fluid and blood sugar values (Table 22). Mean synovial fluid alkaline phosphatase (ALP) activity (Table 22) for hydrarthrosis of tibiotarsal joints was slightly lower than its corresponding serum ALP value; however, this was not statistically significant. The mean values for synovial fluid LDH, GOT, and GPT activity were all significantly ($P = 0.001$) lower than their corresponding serum values (Table 22).

The mean total erythrocyte and leukocyte values for synovial effusions from tibiotarsal joints affected with hydrarthrosis were, in general, low (Table 23). Lymphocytes and monocytes were the predominant cell types encountered. The low absolute number of neutrophils in synovial effusions reflected the transudative nature of the effusions investigated.

Hematologic Data

Hematologic data for cattle affected with degenerative joint disease, acute or chronic traumatic arthritis, or hydrarthrosis of the tibiotarsal joint are presented in Table 24.

TABLE 22. Summary of Physical and Chemical Data for Blood, Serum, and Synovial Fluid for Cattle Affected with Tarsal Hydrarthrosis

	No. of Joint Samples		No. of Blood or Serum Samples	
Total volume (cc./joint)	10	73.00 ± 18.11* (20 - 185)**		
Gross appearance	10	N NO NOF AOF*** 6 1 1 2		
Relative Viscosity at 38.6 C.	10	2.16 ± 0.14 (1.48 - 2.90)		
Mucinous precipitate quality	10	N F P VP**** 6 3 1 0		
Sugar values (mg./100 ml.)	10	63.70 ± 4.26a (37 - 75)	8	62.25 ± 4.27 (45 - 78)
Alkaline phosphatase activity (Sigma Units/ml.)	10	2.29 ± 0.55a (0.10 - 5.15)	8	2.35 ± 0.51 (0.95 - 5.25)
Lactic dehydrogenase activity (LDH Units/ml.)	7	225 ± 128b (8 - 387)	6	1925 ± 314 (1665 - 2360)
Glutamic oxalacetic transaminase activity (Sigma-Frankel Units/ml.)	7	19.29 ± 8.65b (0 - 70)	6	75.83 ± 4.03 (55 - 95)
Glutamic pyruvic transaminase activity (Sigma-Frankel Units/ml.)	7	6.57 ± 1.13b (0 - 8)	6	24.33 ± 3.28 (13 - 38)

*Standard error of the mean. **Range of values for the respective constituents.

***Gross appearance of the synovial fluid: N = normal (colorless and clear); NO = colorless and opaque; NOF = colorless and opaque, with some flocculent material; and AOF = amber and opaque, with some flocculent material.

****Mucinous precipitate quality graded: N = normal; F = fair; P = poor; and VP = very poor.

[a]No statistically significant difference between synovial fluid and its corresponding blood or serum values.

[b]Significantly (P = 0.001) lower than its corresponding serum values.

TOTAL 23. Total Numbers of Erythrocytes and Leukocytes, and Absolute Numbers of Various Leukocytes in Synovial Fluid from Cattle Affected with Tarsal Hydrarthrosis

	No. of Joint Samples	Range	Mean
Erythrocytes x 10^3/cmm.	10	0 to 12.00	1.56 ± 1.17*
Leukocytes/cmm.	10	11 to 1800	285.00 ± 172.15
Leukocytes/cmm.	10		
Neutrophils		0 to 10	3.01 ± 1.25
Lymphocytes		0 to 918	138.50 ± 88.85
Monocytes		0.66 to 882	126.04 ± 84.79
Macrophages		0 to 8.80	3.45 ± 1.18
Eosinophils		0 to 0.11	0.01 ± 0.00

*Standard error of the mean.

TABLE 24. Hematologic Data for Cattle Affected with Degenerative Joint Disease, Acute or Chronic Traumatic Arthritis, or Tarsal Hydrarthrosis

	No.	Degenerative Joint Disease	No.	Traumatic Arthritis Acute	No.	Traumatic Arthritis Chronic	No.	Hydrarthrosis
Hemoglobin (gms./100 ml.)	30	11.4 ± 0.4* (8.0 - 15.0)**	7	11.5 ± 0.3 (10.3 - 12.6)	6	11.3 ± 0.5 (10.3 - 13.0)	7	12.9 ± 0.6 (11.4 - 15.0)
Packed Cell Volume(%)	30	32.7 ± 1.1 (26 - 46)	7	31.2 ± 0.6 (30 - 35)	6	31.0 ± 1.7 (24 - 35)	7	37.9 ± 2.1 (32 - 34)
Leukocytes x 10^3/cmm.	30	7.99 ± 0.57 (3.30 - 15.00)	7	10.71 ± 1.59 (7.50 ± 18.60)	6	10.33 ± 1.29 (3.85 ± 13.65)	6	9.14 ± 0.66 (6.60 - 13.70)
Differential (%)								
Neutrophils	29	44.5 ± 3.5 (10 - 83)	7	38.1 ± 5.3 (13 - 52)	6	40.3 ± 5.4 (20 - 58)	7	34.3 ± 4.8 (26 - 57)
Segmented		38.2 ± 3.3 (7 - 77)		26.6 ± 5.8 (8 - 51)		34.8 ± 5.6 (14 - 55)		27.3 ± 2.8 (21 - 42)
Nonsegmented		5.2 ± 1.2 (0 - 12)		10.1 ± 5.2 (0 - 40)		5.5 ± 1.6 (0 - 12)		7.1 ± 1.2 (0 - 29)
Lymphocytes		44.3 ± 2.9 (9 - 85)		54.17 ± 4.7 (44 - 80)		55.8 ± 4.7 (42 - 76)		50.4 ± 4.6 (35 - 67)
Monocytes		4.8 ± 0.8 (0 - 13)		4.3 ± 1.3 (1 - 9)		3.2 ± 1.3 (0 - 9)		5.1 ± 1.3 (1 - 11)
Eosinophils		6.6 ± 1.4 (0 - 24)		3.1 ± 1.3 (0 - 9)		1.2 ± 0.8 (0 - 5)		10.4 ± 4.6 (0 - 37)
Basophils		0.1 ± 0.08 (0 - 2)		0.3 ± 0.1 (0 - 1)		0.0 ± 0.0 (0)		0.0 ± 0.0 (0)

*Standard error of the mean

**Range of values.

Cattle affected with acute or chronic traumatic arthritis had the highest total leukocyte counts. Cattle affected with acute traumatic arthritis demonstrate a minor increase in nonsegmented neutrophils.

Group II--Intermediate Synovial Effusions

Idiopathic Arthritis

The joints of 17 cattle (Table 25) of various breeds, ranging in age from 2 weeks to 8 years, with a mean age of 3.4 $\pm$ 0.7 years, were affected with an idiopathic arthritis. Two bull calves, 2 heifers, 11 cows, and 2 steers comprised the group investigated. Failure to determine a specific etiologic agent resulted in the classification of these joint effusions as idiopathic in nature. The tibiotarsal joint was most frequently involved, and accounted for 64.7% of the total number of joints examined. All cattle affected with an idiopathic arthritis were found to be free of any systemic disease.

Clinical examination revealed joints that were grossly similar to joints infected with a specific microorganism. All attempts to culture microorganisms from the synovial effusions of cattle affected with an idiopathic synovitis met with negative results.

The total volume and gross appearance of the synovial effusions were observed and recorded (Table 26) immediately following arthrocentesis. Almost all synovial

TABLE 25. Incidence and Pathologic Classification of Synovial Effusions from the Joints of Cattle Affected with an Idiopathic Arthritis

No.	Breed	Age	Sex	Joint(s)	Classification*
1	Holstein-Friesian	7.0 yrs.	Cow	Left Intercarpal	Chronic
2	Holstein-Friesian	5.0 yrs.	Cow	Left Intercarpal	Chronic
3	Holstein-Friesian	2.0 yrs.	Heifer	Right Tibiotarsal	Subacute
4	Holstein-Friesian	8.0 yrs.	Cow	Left Tibiotarsal	Acute
5	Guernsey	10 mo.	Heifer	Right Tibiotarsal	Chronic
6	Hereford	8 mo.	Steer	Left Femoropatellar	Chronic
7	Holstein-Friesian	5.0 yrs.	Cow	Left Tibiotarsal	Acute
8	Holstein-Friesian	5.0 yrs.	Cow	Left Metatarsophalangeal	Chronic
9	Holstein-Friesian	2 wks.	Bull	Right Tibiotarsal	Acute
10	Holstein-Friesian	5.0 yrs.	Cow	Left Tibiotarsal	Acute
11	Hereford	1.0 yr.	Steer	Right Femoropatellar	Chronic
12	Holstein-Friesian	5.0 yrs.	Cow	Right Tibiotarsal	Chronic
13	Holstein-Friesian	2.0 yrs.	Heifer	Right Metacarpophalangeal	Chronic
14	Holstein-Friesian	8.0 yrs.	Cow	Right Tibiotarsal	Chronic
15	Holstein-Friesian	2 mo.	Bull	Right Tibiotarsal	Subacute
16	Holstein-Friesian	6 mo.	Heifer	Right Intercarpal	Chronic
17	Holstein-Friesian	3.0 yrs.	Cow	Right Tibiotarsal	Subacute

*Classified on the basis of history, clinical examination, and synovial fluid analyses as acute, subacute, and chronic.

TABLE 26. Total Volume and Gross Appearance of Synovial Fluid from the Joints of Cattle Affected with an Idiopathic Arthritis

Joints	No. of Joint Samples	Total Volume (cc./joint)	Gross Appearance*			
			YOF	TY	TYF	SS
Radiocarpal	1	5.00 ± 0.00 ($\bar{0}$)	0	1	0	0
Intercarpal	1	8.00 ± 0.00 ($\bar{0}$)	1	0	0	0
Metacarpo-phalangeal	1	2.50 ± 0.00 ($\bar{0}$)	0	0	1	0
Femoro-patellar	2	24.75 ± 20.30** (4.5 - 45.00)***	0	0	0	2
Tibiotarsal	11	26.64 ± 8.72 (6.5 - 106.0)	1	3	6	1
Metatarso-phalangeal	1	2.00 ± 0.00 ($\bar{0}$)	0	1	0	0

*Gross appearance of the synovial fluid: YOF = pale yellow and opaque, with some flocculent material; YT = turbid and yellow, with some flocculent material; and SS = serosanguineous.

**Standard error of the mean.

***Range of values for the respective joints.

effusions were exudative in nature and, in the case of the femoropatellar and tibiotarsal joints, markedly increased in volume.

A reduced relative viscosity was recorded for synovial effusions from the various joints (Table 27). Depolymerization of the synovial mucopolysaccharide of the synovial effusions was indicated by the large number of poorer grades of mucinous precipitate.

A mean sugar value of 52.25 ± 8.02 milligrams/100 ml. of synovial fluid was obtained for all joints and was 32.7% lower than the mean blood sugar level. This value proved to be significantly ($P = 0.001$) lower than the mean value of 77.53 ± 6.95 mg. of sugar/100 ml. of blood obtained for these animals. Sugar values for other joints were found to vary in comparison to their blood sugar values (Table 28). A sufficient number of synovial fluid specimens obtained from the tibiotarsal joints revealed that the mean sugar value for this joint was significantly ($P = 0.001$) lower than its corresponding mean blood sugar value.

A mean alkaline phosphatase (ALP) activity of 6.01 ± 1.08 Sigma units/ml. of synovial fluid was obtained for all joints. This value proved to be significantly ($P = 0.001$) greater than the mean value of 1.83 ± 0.36 Sigma units/ml. of serum obtained for these animals. The ALP activity of synovial effusions from the tibiotarsal joint was found to be

TABLE 27. Relative Viscosity and Mucinous Precipitate Quality of Synovial Fluid from the Joints of Cattle Affected with an Idiopathic Arthritis

Joints	No. of Joint Samples	Relative Viscosity* Range	Relative Viscosity* Mean	No. of Joint Samples	Mucinous Precipitate Qual.** N	F	P	VP
Radiocarpal	1	0	2.04 ± 0.00	1	0	0	1	0
Intercarpal	1	0	3.33 ± 0.00	1	1	0	0	0
Metacarpophalangeal	1	0	QNS***	1	0	0	0	1
Femoropatellar	1	0	3.81 ± 0.00	2	0	0	1	1
Tibiotarsal	11	1.56 to 5.54	3.29 ± 0.45****	11	1	3	4	3
Metatarsophalangeal	1	0	QNS	1	1	0	0	0

*Relative viscosity determinations were made at 38.6 C.

**Mucinous precipitate quality graded: N = normal; F = fair; P = poor; and VP = very poor.

***QNS = quantity nonsufficient for a determination.

****Standard error of the mean.

TABLE 28. A Comparison of Synovial Fluid and Blood Sugar Values for Cattle Affected with an Idiopathic Arthritis

Joints	No. of Joint Samples*	Mg. Synovial Sugar/ 100 ml. Range	Mg. Synovial Sugar/ 100 ml. Mean	No. of Blood Samples	Mg. Blood Sugar/ 100 ml. Range	Mg. Blood Sugar/ 100 ml. Mean
Radiocarpal	1	0	26.00 ± 0.00	1	0	67.00 ± 0.00
Intercarpal	1	0	63.00 ± 0.00	1	0	65.00 ± 0.00
Metacarpo-phalangeal	1	0	0.00 ± 0.00	1	0	90.00 ± 0.00
Femoropatellar	2	7 to 68	37.50 ± 30.58**	2	61 to 64	62.50 ± 1.42
Tibiotarsal	11	5 to 109	59.45 ± 9.98***	11	48 to 101	72.91 ± 5.58
Metatarso-phalangeal	1	0	70.00 ± 0.00	1	0	170.00 ± 0.00
Total Values	17	0 to 109	52.24 ± 8.02***	17	48 to 170	77.53 ± 6.95

*For each animal, synovial fluid and blood sugar values were determined.

**Standard error of the mean.

***Significantly (P = 0.001) lower than the corresponding blood value.

significantly (P = 0.001) greater than its respective serum ALP activity obtained for these animals (Table 29). An insufficient number of samples did not permit statistical analyses to be made on specimens from joints other than the tibiotarsal joint.

When the total mean synovial fluid lactic dehydrogenase (LDH) activity of 861 ± 236 LDH units/ml. was compared with its serum counterpart of 1560 ± 209 LDH units/ml., it was found to be significantly (P = 0.001) lower. The LDH activity for synovial fluid from one radiocarpal joint was observed to attain a level comparable to serum LDH activity (Table 30) for cattle in this group.

A comparison between the mean synovial fluid glutamic oxalacetic transaminase (SY-GOT) activity and mean serum glutamic oxalacetic transaminase (S-GOT) activity revealed no statistically significant differences (Table 31). A value of 71.00 ± 16.29 Sigma-Frankel units/ml. was obtained for serum. This value closely compared with the mean SY-GOT value of 70.60 ± 29.07 Sigma-Frankel units/ml. obtained for all joints affected with an idiopathic synovitis.

The mean synovial fluid glutamic pyruvic transaminase (SY-GPT) value of 20.00 ± 12.00 Sigma-Frankel units/ml. was found to be significantly (P = 0.01) higher than the corresponding serum glutamic pyruvic transaminase (S-GPT) activity of 11.80 ± 1.68 Sigma-Frankel units/ml. of serum for cattle affected with an idiopathic synovitis (Table 32).

TABLE 29. A Comparison of Synovial Fluid and Serum Alkaline Phosphatase Activity Values for Cattle Affected with an Idiopathic Arthritis

Joints	No. of Joint Samples*	Sigma Units/ml. of Synovial Fluid	No. of Serum Samples	Sigma Units/ml. of Serum
Radiocarpal	1	2.60 ± 0.00 ($\bar{0}$)	1	1.95 ± 0.00 ($\bar{0}$)
Intercarpal	1	13.85 ± 0.00 ($\bar{0}$)	1	1.55 ± 0.00 ($\bar{0}$)
Femoropatellar	2	4.65 ± 0.25** (4.40 - 4.90)***	2	1.39 ± 0.35 (1.03 - 1.75)
Tibiotarsal	7	5.94 ± 1.34**** (1.50 - 11.72)	7	2.07 ± 0.60 (0.40 - 4.30)
Metatarso-phalangeal	1	4.80 ± 0.00 ($\bar{0}$)	1	1.20 ± 0.00 ($\bar{0}$)
Total Values	12	6.01 ± 1.08**** (1.50 - 11.72)	12	1.83 ± 0.36 (0.40 - 4.30)

*For each animal, synovial fluid and serum alkaline phosphatase activity values were determined.

**Standard error of the mean.

***Range of values for the respective joints and serum values.

****Significantly (P = 0.001) higher than corresponding serum value.

TABLE 30. A Comparison of Synovial Fluid and Serum Lactic Dehydrogenase Activity Values for Cattle Affected with an Idiopathic Arthritis

Joints	Samples*	LDH Units/ml of Synovial Fluid	Samples	LDH Units/ml. of Serum
Radiocarpal	1	1430 ± 0 (0)	1	1900 ± 0 (0)
Femoropatellar	1	328 ± 0 (0)	1	1210 ± 0 (0)
Tibiotarsal	3	849 ± 239** (347 - 1360)***	3	1563 ± 331 (930 - 2060)
Total Values	5	861 ± 236**** (328 - 1430)	5	1560 ± 209 (930 - 2060)

*For each animal, synovial fluid and serum lactic dehydrogenase activity values were determined.

**Standard error of the mean.

***Range of values for the respective joints and serum values.

****Significantly (P = 0.001) lower than corresponding serum value.

TABLE 31. A Comparison of Synovial Fluid and Serum Glutamic Oxalacetic Transaminase Activity Values for Cattle Affected with an Idiopathic Arthritis

Joints	Samples*	Sigma-Frankel Units/ml. of Synovial Fluid	Samples	Sigma-Frankel Units/ml. of Serum
Radiocarpal	1	74.00 ± 0.00 ($\bar{0}$)	1	58.00 ± 0.00 ($\bar{0}$)
Femoropatellar	1	180.00 ± 0.00 ($\bar{0}$)	1	115.00 ± 0.00 ($\bar{0}$)
Tibiotarsal	3	33.00 ± 11.07** (20 - 55)***	3	60.67 ± 24.75 (13 - 95)
Total Values	5	70.60 ± 29.07**** (20 - 180)	5	71.00 ± 16.29 (13 - 115)

*For each animal, synovial fluid and serum glutamic oxalacetic transaminase activity values were determined.

**Standard error of the mean.

***Range of values for the respective joints and serum samples.

****No statistically significant difference was encountered between synovial fluid and serum.

TABLE 32. A Comparison of Synovial Fluid and Serum Glutamic Pyruvic Transaminase Activity Values for Cattle Affected with an Idiopathic Arthritis

Joints	No. of Synovial Samples*	Sigma-Frankel Units/ ml. of Synovial Fluid	No. of Serum Samples	Sigma-Frankel Units/ml. of Serum
Radiocarpal	1	67.00 ± 0.00 ($\overline{0}$)	1	18.00 ± 0.00 ($\overline{0}$)
Femoro-patellar	1	13.00 ± 0.00 ($\overline{0}$)	1	11.00 ± 0.00 ($\overline{0}$)
Tibiotarsal	3	6.67 ± 4.06** (0 - 14)***	3	10.00 ± 1.16 (8 - 12)
Total Values	5	20.00 ± 12.00**** (0 - 67)	5	11.80 ± 1.68 (8 - 18)

*For each animal, synovial fluid and serum glutamic pyruvic transaminase activity values were determined.

**Standard error of the mean.

***Range of values for the respective joints and serum samples.

****Significantly (P = 0.01) greater than the corresponding serum value.

With the exception of one intercarpal joint, increased numbers of erythrocytes and leukocytes were recorded for synovial effusions from the various joints affected with an idiopathic synovitis (Table 33). Synovial effusions from the femoropatellar joints contained the highest total numbers of erythrocytes and leukocytes. The exudative nature of these synovial effusions was reflected by the proportionally higher absolute number of polymorphonuclear neutrophils in relation to the other various types of leukocytes (Table 34). Lymphocytes accounted for the major portion of the remaining synovial fluid leukocytes.

Hematologic Data

The hematologic data for cattle affected with an idiopathic arthritis (Table 35) revealed a reduction in the packed cell volume (PCV) which ranged from 26.5% to 41.5% with a mean of 30.7 $\pm$ 1.3%. There was a marked increase in the relative number of neutrophils (50.2 $\pm$ 5.2%), with a pronounced increase in the relative number of nonsegmented neutrophils (11.2 $\pm$ 3.5%).

TABLE 33. Total Numbers of Erythrocytes and Leukocytes in Synovial Fluid from the Joints of Cattle Affected with an Idiopathic Arthritis

Joints	No. of Joint Samples	RBC x 10^3/cmm.	WBC x 10^3/cmm.
Radiocarpal	1	717.00 ± 0.00 ($\bar{0}$)	3.51 ± 0.00 ($\bar{0}$)
Intercarpal	1	0.00 ± 0.00 ($\bar{0}$)	10.25 ± 0.00 ($\bar{0}$)
Metacarpo-phalangeal	1	10.90 ± 0.00 ($\bar{0}$)	79.50 ± 0.00 ($\bar{0}$)
Femoropatellar	2	1585.20 ± 1524.46* (11.40 - 3160.00)**	91.31 ± 42.16 (31.87 - 150.75)
Tibiotarsal	11	84.65 ± 62.06 (0 - 690.00)	49.52 ± 12.99 (0.25 - 150.75)
Metatarso-phalangeal	1	3.33 ± 0.00 ($\bar{0}$)	0.24 ± 0.00 ($\bar{0}$)

*Standard error of the mean.

**Range of values for the respective joints.

TABLE 34. Absolute Numbers of Various Leukocytes in Synovial Fluid from the Joints of Cattle Affected with an Idiopathic Arthritis

Joints	No.	Absolute Number of Leukocytes x 10^3/cmm. Neutrophils	Lymphocytes	Monocytes	Macrophages	Eosinophils
Radiocarpal	1	2.07 ± 0.00 ($\bar{0}$)	1.09 ± 0.00 ($\bar{0}$)	0.32 ± 0.00 ($\bar{0}$)	0.04 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)
Intercarpal	1	8.61 ± 0.00 ($\bar{0}$)	1.54 ± 0.00 ($\bar{0}$)	0.10 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)
Metacarpo-phalangeal	1	73.32 ± 0.00 ($\bar{0}$)	0.79 ± 0.00 ($\bar{0}$)	2.39 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)
Femoro-patellar	2	83.00 ± 0.00* (27.40 - 76.44)**	2.42 ± 2.10 (0.32 - 4.52	4.61 ± 1.42 (3.19 - 6.03)	0.48 ± 0.00 (0 - 0.96)	0.00 ± 0.00 ($\bar{0}$)
Tibiotarsal	11	47.28 ± 12.46 (0.07 - 107.83)	0.88 ± 0.82 (0 - 6.82)	0.65 ± 0.30 (0 - 1.49)	0.98 ± 0.60 (0 - 0.96)	0.001 ± 0.00 (0 - 0.012
Metatarso-phalangeal	1	0.007 ± 0.00 ($\bar{0}$)	0.11 ± 0.00 ($\bar{0}$)	0.12 ± 0.00 ($\bar{0}$)	0.007 ± 0.00 ($\bar{0}$)	0.00 ± 0.00 ($\bar{0}$)

*Standard error of the mean.

**Range of values for the respective joints.

TABLE 35. Hematologic Data from Cattle Affected with an Idiopathic Arthritis

	Range	Mean
Hemoglobin (gms./100 ml.)	8.5 to 14.3	10.5 ± 0.4*
Packed cell volume (%)	26.5 to 41.5	30.7 ± 1.3
Leukocytes x 10^3/cmm.	3.5 to 20.7	9.32 ± 1.45
Differential (%)		
Neutrophils	18 to 85	50.2 ± 5.2
Segmented	17 to 53	38.9 ± 3.2
Nonsegmented	0 to 38	11.2 ± 3.5
Lymphocytes	13 to 76	41.5 ± 5.1
Monocytes	1 to 19	5.1 ± 1.3
Eosinophils	0 to 9	3.2 ± 0.8
Basophils	0 to 1	0.2 ± 0.1

*Standard error of the mean.

Group III--Septic Synovial Effusions

Infectious Arthritis Due to Bacteria

Eighteen joints of 14 cattle (Table 36) of various breeds were affected with an infectious arthritis as established by bacteriologic studies of the synovial effusions. Monarticular infectious arthritis accounted for 71.4% of the animals examined, while the remainder of the joint infections were polyarticular; however, polyarticular infectious arthritis in this investigation never exceeded 2 joints per animal. The cattle utilized in this study ranged in age from 5 days to 15 years, with a mean age of 3.6 $\pm$ 0.9 years. Three of the animals were bulls, 5 were cows, 5 were heifers, and 1 was a steer. Secondary infectious arthritis was the most prevalent form of joint infection and accounted for 75% of all joints investigated. Of the various microorganisms isolated from septic synovial effusions, Corynebacterium pyogenes was the most commonly encountered, accounting for 35% of the isolates; this was closely followed by members of the genus Streptococcus, which accounted for 25% of the number of microorganisms isolated. Mixed infections were encountered in 16.6% of the total number of joints. The tibiotarsal joint was most frequently infected, accounting for 56% of the total number of joints investigated. Infectious arthritis of the tibiotarsal joint occurred most frequently in cows confined to stanchions and resulted from

TABLE 36. Pathologic Classification of Synovial Effusions and Identification of Microorganisms Isolated from the Joints of Cattle with Infectious Arthritis Due to Bacteria

No.	Breed	Age	Sex	Joint(s)	Pathologic Classification*		
					Duration of Effusion	Mode of Infection	Microorganism(s)
1	Holstein-Friesian	3 yrs.	Bull	Right Tibiotarsal	Chronic	Secondary	Corynebacterium pyogenes
2	Hereford	15 yrs.	Cow	Left Tibiotarsal	Chronic	Tertiary	Micrococcus caseolyticus Proteus spp.
3	Holstein-Friesian	2 mo.	Bull	Left Tibiotarsal	Subacute	Tertiary	Corynebacterium pyogenes Escherichia coli Streptococcus viridans
4	Holstein-Friesian	7 yrs.	Cow	Left Radiocarpal	Chronic	Secondary	Streptococcus spp.
				Left Intercarpal	Chronic	Secondary	Streptococcus spp.
5	Holstein-Friesian	5 days	Heifer	Left Tibiotarsal	Acute	Tertiary	Corynebacterium pyogenes Streptococcus spp.

*Infectious arthritis was classified on the basis of: (1) duration of effusion (acute, subacute, or chronic); (2) mode of joint infection (primary = penetration of a foreign object into the joint cavity; secondary = extension of infection from an area of infection adjacent to the joint cavity; tertiary = associated with a septicemia or metatastasis from an area of infection in some part of the body not adjacent to the joint cavity); and (3) microorganism(s) isolated from the synovial effusion.

TABLE 36--Continued

No.	Breed	Age	Sex	Joint(s)	Pathologic Classification: Duration of Effusion	Pathologic Classification: Mode of Infection	Microorganism(s)
6	Holstein-Friesian	8 mo.	Steer	Right Femoropatellar	Chronic	Primary	Corynebacterium pyogenes
7	Holstein-Friesian	5 yrs.	Cow	Left Tibiotarsal	Chronic	Secondary	Corynebacterium pyogenes
8	Guernsey	1 yr.	Heifer	Left Metatarsophalangeal	Chronic	Secondary	Streptococcus spp.
9	Hereford	2 yrs.	Bull	Left Tibiotarsal	Chronic	Secondary	Staphylococcus aureus
				Right Tibiotarsal	Chronic	Secondary	Proteus mirabilis
10	Aberdeen-Angus	1 yr.	Heifer	Left Intercarpal	Chronic	Secondary	Corynebacterium pyogenes
11	Holstein-Friesian	9 yrs.	Cow	Left Tibiotarsal	Chronic	Secondary	Flavobacterium spp.
				Right Tibiotarsal	Chronic	Secondary	Bacillus spp.
12	Holstein-Friesian	1 mo.	Heifer	Right Radiocarpal	Subacute	Secondary	Paracolon spp. (Providence type)
13	Holstein-Friesian	6 yrs.	Cow	Right Tibiotarsal	Chronic	Secondary	Enterococcus spp.
				Left Tibiotarsal	Chronic	Secondary	Enterococcus spp.
14	Holstein-Friesian	3 mo.	Heifer	Right Femoropatellar	Chronic	Secondary	Corynebacterium pyogenes

extension from a primary focus of infection on the lateral surface of the tarsus. Repeated trauma and abrasion of the lateral surface of the tarsus at approximately the level of the lateral malleolus of the tibia produced an infectious tenosynovitis of the peroneus longus and extensor digiti quarti (Figure 1). Spread of infection from these tendon sheaths produced the large number of cases of secondary infectious arthritis of the tibiotarsal and proximal intertarsal joints. Affected cattle showed evidence of arthralgia, which resulted in varying degrees of claudication. Infected joints were warm to the touch and any degree of manual manipulation elicited a response to pain in the animal. Many animals were prone to stand with the affected limb in the flexed position. Evidence of a generalized bacteremia or toxemia was evident only in cases of tertiary infectious arthritis.

An increase in the total volume of synovial effusions from infected joints was a constant finding (Table 37). The gross appearance of the effusions varied somewhat with the duration of infection and the type of microorganism involved, with the majority being turbid and yellow in appearance.

Relative viscosity was variable, dependent on which joint the synovial effusion was obtained from (Table 38). Mucinous precipitates of a very poor quality were the predominant type encountered (Table 38).

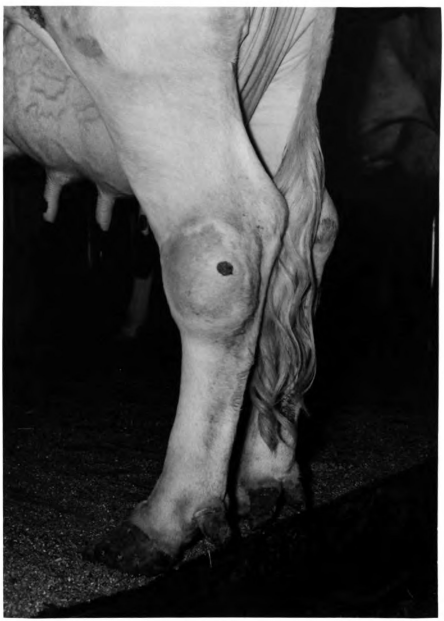

Figure 1. Holstein-Friesian cow with acute infectious tenosynovitis of the peroneus longus and extensor digiti resulting in an acute secondary arthritis of the left tarsus. Corynebacterium pyogenes and Escherichia coli were isolated from the synovial effusion.

TABLE 37. Total Volume and Gross Appearance of Synovial Fluid Obtained from the Joints of Cattle Affected with Infectious Arthritis

Joints	No. of Joint Samples	Total Volume (cc./joint)	Gross Appearance*				
			NOF	AO	AOF	TYF	SS
Radiocarpal	2	4.00 ± 0.00**	0	0	0	2	0
		(3.0 - 5.0)***					
Intercarpal	2	7.00 ± 3.01	0	1	0	1	0
		(4.0 - 10.0)					
Femoro-patellar	2	15.75 ± 9.28	0	0	0	2	0
		(6.5 - 25)					
Tibiotarsal	11	33.89 ± 12.18	1	0	5	3	2
		(2.5 - 125.0)					
Metatarso-phalangeal	1	2.50 ± 0.00	0	0	0	1	0
		(0)					

*Gross appearance of synovial fluid: NOF = colorless and opaque, with some flocculent material; AO = amber and opaque; AOF = amber and opaque, with some flocculent material; TYF = turbid and yellow, with some flocculent material; and SS = serosanguineous.

**Standard error of the mean.

***Range of values for the respective joints.

TABLE 38. Relative Viscosity and Mucinous Precipitate Quality of Synovial Fluid from the Joints of Cattle Affected with Infectious Arthritis

Joints	Samples	Relative Viscosity*		Mucinous Precipitate Quality**			
		Range	Mean	N	F	P	VP
Radiocarpal	1	0	1.24 ± 0.00	0	0	0	1
Intercarpal	2	4.21 to 6.70	5.46 ± 1.24***	0	0	0	2
Femoropatellar	2	1.59 to 2.00	1.80 ± 0.20	0	0	0	2
Tibiotarsal	11	1.31 to 6.77	3.18 ± 0.55	3	2	0	6
Metatarsophalangeal	1	0	8.40 ± 0.00	0	0	0	1

*Relative viscosity determinations were made at 38.6 C.

**Mucinous precipitate quality graded: N = normal; F = fair; P = poor; and VP = very poor.

***Standard error of the mean.

All synovial fluid sugar levels were lower than their respective blood sugar levels (Table 39). A mean sugar level of 36.22 ± 6.08 mg./100 ml. of synovial fluid was determined for all joints, with a corresponding mean blood sugar level of 69.57 ± 6.37 mg./100 ml. of blood. The reduction in the mean synovial fluid sugar level for all joints was highly significant (P = 0.001); this represented a 48% drop in sugar level when compared with the whole blood sugar level for the entire group of cattle.

A comparison between the mean synovial fluid alkaline phosphatase (ALP) activity of 3.98 ± 0.76 Sigma units/ml. for all joints with infectious arthritis proved to be significantly (P = 0.01) higher than the mean value of 2.63 ± 0.23 Sigma units/ml. obtained for serum alkaline phosphatase (ALP) activity from these animals (Table 40).

Elevated erythrocyte and leukocyte counts were recorded for synovial effusions from various joints infected with a variety of microorganisms (Table 41). The exudative nature of these joint effusions was reflected by the high absolute number of neutrophils in contrast to low absolute counts for the other synovial fluid cell types (Table 42).

TABLE 39. A Comparison of Synovial Fluid and Blood Sugar Values for Cattle Affected with Infectious Arthritis

Joints	No. of Joint Samples*	Mg. Synovial Sugar/100 ml. Range	Mg. Synovial Sugar/100 ml. Mean	No. of Blood Samples	Mg. Blood Sugar/100 ml. Range	Mg. Blood Sugar/100 ml. Mean
Radiocarpal	2	0 to 25	12.50 ± 0.00**	2	50 to 68	59.00 ± 9.03
Intercarpal	2	0 to 76	38.00 ± 0.00	2	30 to 71	60.50 ± 10.52
Femoropatellar	2	9 to 39	24.00 ± 15.04	2	39 to 50	44.50 ± 5.50
Tibiotarsal	11	0 to 64	40.09 ± 6.96***	8	50 to 115	78.50 ± 9.47
Metatarso-phalangeal	1	0	62.00 ± 0.00	1	0	68.00 ± 0.00
Total Values	18	0 to 76	36.22 ± 6.08***	15	30 to 115	69.57 ± 6.37

*For each animal, synovial fluid and blood sugar values were determined.

**Standard error of the mean.

***Significantly (P = 0.001) lower than corresponding blood value.

TABLE 40. A Comparison of Synovial Fluid and Serum Alkaline Phosphatase Activity Values for Cattle Affected with Infectious Arthritis

Joints	No.of Joint Samples*	Sigma Units/ml. of Synovial Fluid	No.of Serum Samples	Sigma Units/ml. of Serum
Radiocarpal	2	1.40 ± 0.16** (1.25 - 1.55)***	2	1.83 ± 1.08 (0.75 - 2.90)
Intercarpal	2	10.35 ± 4.28 (6.10 - 14.6)	2	1.34 ± 0.57 (0.75 - 1.90)
Femoropatellar	2	2.58 ± 2.33 (0.25 - 4.90)	2	2.58 ± 0.72 (1.85 - 3.30)
Tibiotarsal	9	4.38 ± 0.89***** (0.70 - 9.50)	6	2.43 ± 0.99 (0.60 - 6.60)
Metatarso-phalangeal	1	12.65 ± 0.00 ($\overline{0}$)	1	6.35 ± 0.00 ($\overline{0}$)
Total Values	16	3.98 ± 0.76**** (0.25 - 14.60)	13	2.63 ± 0.23 (0.60 - 6.35)

*For each animal, synovial fluid and serum alkaline phosphatase activity values were determined.

**Standard error of the mean.

***Range of values for the respective joints and serum.

****Significantly (P = 0.01) greater than corresponding serum value.

*****Significantly (P = 0.05) greater than corresponding serum value.

TABLE 41. Total Numbers of Erythrocytes and Leukocytes for Synovial Fluid from the Joints of Cattle Affected with Infectious Arthritis

Joints	No. of Joint Samples	RBC x 10^3/cmm.	WBC x 10^3/cmm.
Radiocarpal	2	2.60 ± 1.60* (1.00 - 4.20)**	16.33 ± 3.28 (5.66 - 26.00)
Intercarpal	2	24.00 ± 0.00 (0 - 24.00)	55.07 ± 53.49 (1.73 - 108.40)
Femoropatellar	2	6.70 ± 0.00 (0 - 6.70)	1643.55 ± 1638.00 (7.10 - 3280.00)
Tibiotarsal	11	54.80 ± 48.66 (0 - 550.00)	64.13 ± 34.78 (0.02 - 387.00)
Metatarso-phalangeal	1	12.66 ± 0.00 (0)	2.20 ± 0.00 (0)

*Standard error of the mean.

**Range of values for the respective joints.

TABLE 42. Absolute Numbers of Various Leukocytes in Synovial Fluid from the Joints of Cattle Affected with Infectious Arthritis

Joints	No.	Absolute Number of Leukocytes x 10^3/cmm. Neutrophils	Lymphocytes	Monocytes	Macrophages	Eosinophils
Radiocarpal	2	15.88 ± 2.82* (4.75 - 26.00)**	0.11 ± 0.00 (0 - 0.11)	0.51 ± 0.00 (0 - 0.51)	0.28 ± 0.00 (0 - 0.28)	0.00 ± 0.00 ($\overline{0}$)
Intercarpal	2	52.17 ± 52.04 (0.28 - 104.06)	0.78 ± 0.00 (0 - 0.78)	1.79 ± 1.46 (0.33 - 3.25)	0.72 ± 0.37 (0.35 - 1.08)	0.00 ± 0.00 ($\overline{0}$)
Femoro-patellar	2	1610.72 ± 160.00 (7.03 - 3214.00)	16.43 ± 16.40 (0.07 - 32.80)	32.80 ± 0.00 (0 - 32.80)	0.00 ± 0.00 ($\overline{0}$)	0.00 ± 0.00 ($\overline{0}$)
Tibiotarsal	11	56.37 ± 32.62 (0.011 - 371.52)	2.76 ± 1.74 (0.022 - 17.00)	0.56 ± 0.33 (0 - 3.87)	0.001 ± 0.001 (0 - 1.08)	0.00 ± 0.00 ($\overline{0}$)
Metatarso-phalangeal	1	2.05 ± 0.00 ($\overline{0}$)	0.02 ± 0.00 ($\overline{0}$)	0.13 ± 0.00 ($\overline{0}$)	0.00 ± 0.00 ($\overline{0}$)	0.00 ± 0.00 ($\overline{0}$)

*Standard error of the mean.

**Range of values for the respective joints.

Hematologic Data

The hematologic data for cattle affected with infectious arthritis (Table 43) revealed a reduced packed cell volume (PCV) which ranged from 19% to 41.5% with a mean of 31.7 ± 1.8%. The mean total leukocyte count of 17.37 ± 7.08 x 10^3/cmm. was markedly elevated. The total leukocyte count ranged from 6.5 to 80.0 x 10^3/cmm. There was a marked increase in the relative number of neutrophils (58.67 ± 6.90%), with a pronounced shift to the left as denoted by an increase in the relative number of nonsegmented neutrophils (13.17 ± 4.26%).

TABLE 43. Hematologic Data from Cattle Affected with Infectious Arthritis

	Range	Mean
Hemoglobin (gms./100 ml.)	6.8 to 14.3	10.6 ± 0.7*
Packed cell volume (%)	19 to 41.5	31.7 ± 1.8
Leukocytes x 10^3/cmm.	6.5 to 80.0	17.37 ± 7.08
Differential (%)		
Neutrophils	15 to 90	58.67 ± 6.90
Segmented	14 to 68	38.00 ± 4.99
Nonsegmented	0 to 45	13.17 ± 4.26
Lymphocytes	10 to 76	34.33 ± 6.05
Monocytes	0 to 19	3.92 ± 1.47
Eosinophils	0 to 18	3.08 ± 1.56
Basophils	0	0

*Standard error of the mean.

Anamnesis and Clinical, Gross, and Histopathologic Observations

Degenerative Joint Disease

Anamnesis and Clinical Observations

Nine joints of 3 cows and 4 bulls ranging in age from 2 to 11 years, with a mean age of 6.1 ± 1.2 years, were affected with degenerative joint disease. Eight tarsal joints and 1 femoropatellar joint were investigated.

Cattle affected with degenerative joint disease in general had a history of arthralgia, with or without an associated crepitus on locomotion. Some of the animals were prone to poor tarsal conformation, exhibiting various degrees of tarsoptosis (sickle hocks) often associated with tarsal valgum (cow hocked). Gross distention of the joint capsule was not a consistent clinical feature.

Gross Pathologic Observations

Gross lesions in the joints were confined primarily to the articular cartilages and consisted primarily of a loss in the normal hyaline appearance of the articular cartilage, with a marked tendency for it to become yellowish to dull-white in color in the more advanced cases. In some instances the articular cartilages had undergone softening with the formation of small vesicles on the *stratum superficialis* (Figure 2) which, when expressed, exuded a clear

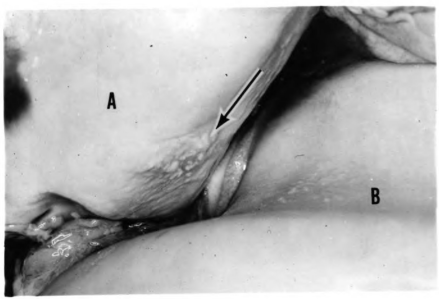

Figure 2. The left femoropatellar joint of a 5-year-old Shorthorn bull. Small vesicles (arrow) can be seen on the articular surface of the patella (A) and on the distal intracondylar groove of the femur (B).

viscous liquid. Ruptured vesicles left small depressions with fimbriated borders in the articular cartilage. Pits and eroded depressions were frequently observed on articular surfaces. In some instances cartilaginous erosion was so severe that the subchondral bone was exposed. In long standing cases where the subchondral bone was exposed, there was evidence of eburnation associated with grooving (Figure 3) in accordance with the movements of the particular joint surface involved. Periarticular margins were often quite pronounced due to a combined loss of their articular cartilages and the formation of marginal osteophytes. The stratum fibrosum of the joint capsule in many instances had undergone fibrosis and the stratum synoviale had undergone hyperplasia and hypertrophy of its villi. Some synovial villi appeared sessile in nature and were composed predominantly of adipose tissue, whereas the majority of the villi were pedunculated; in some cases, extensive villous proliferation gave the lining synovial membrane a fimbriated appearance.

Synovial fluid from joints affected with degenerative joint disease was generally colorless, with occasional samples a pale-amber to pale-yellow in color, opaque, and contained suspended flocculent debris. Total quantity of synovial fluid rarely appeared to be in excess of normal.

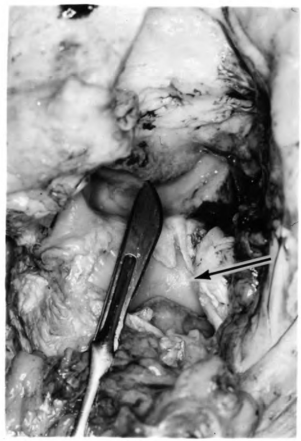

Figure 3. The left tarsal joint of a 5-year-old Shorthorn bull. Erosion and grooving (arrow) of the articular cartilage covering the distal trochlea of the tibiotarsal bone can be seen.

Histopathologic Observations

Synovial Membranes

In general there was evidence of a moderate hyperplasia and hypertrophy of the synovial villi. The synovial intimal cells were observed to undergo hyperplasia in some areas (Figure 4 and 5), while in other areas of the intimal cell layer, there was a reduction in the number of synovial intimal cells, as well as in their cytoplasm; many appeared fibroblastic in nature with long branching cytoplasmic processes connecting one another in a single continuous layer. Invariably the synovial intimal cell layer had undergone hyalinization or fibrinoid degeneration (Figure 6 and 7). In some cases the entire villus had undergone fibrosis with early loss of the distinct fibrillar arrangement of its collagen bundles. Occasionally deposition of calcium salts (blue with H & E stains) were noted in the fibrous subintimal layer of the stratum synoviale. An occasional specimen was observed in the process of subintimal chondroplasia in the stratum synoviale (Figure 8). Scattered mononuclear cells were observed throughout the subintimal synovial layer. The arteries found in the fibrous and deeper adipose strata of the stratum synoviale and stratum fibrosum had undergone hypertrophy of their medial layers, and in some instances there was endarteritis obliterans. Perivascular fibrosis of synovial vessels varied from one specimen to another. Synovial intimal cells reacted poorly to the PAS stain in cases

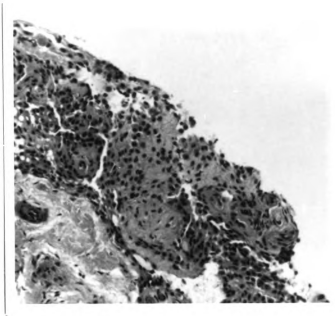

Figure 4. Punch-biopsy specimen from the left tibiotarsal synovial sac of an 11-year-old Aberdeen-Angus bull. Synovial intimal cell hyperplasia in degenerative joint disease. H & E. x187.

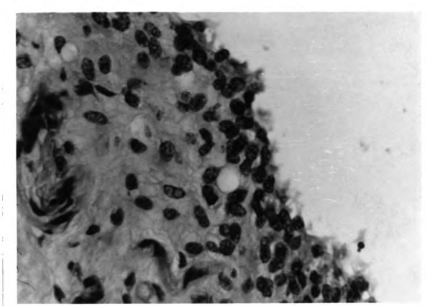

Figure 5. Section of synovial membrane from the left tibiotarsal synovial sac of a 2-year-old Holstein-Friesian cow. Synovial intimal cell hyperplasia in degenerative joint disease with a low ratio of cytoplasm to nucleus in the synovial intimal cells. H & E. x500.

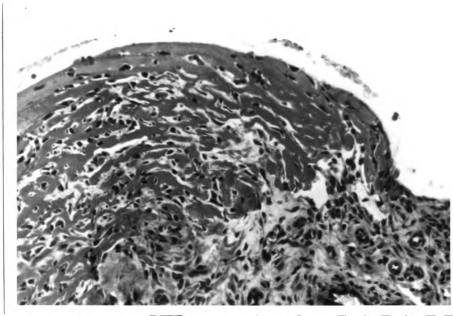

Figure 6. Focal hyalinization of the synovial membrane from the left tibiotarsal synovial sac. H & E. x187.

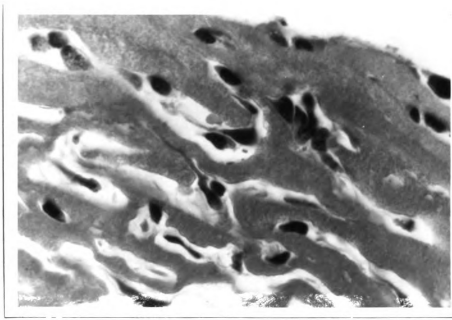

Figure 7. Hyalinization of the synovial intimal cell layer. Higher magnification of Figure 6. H & E. x750.

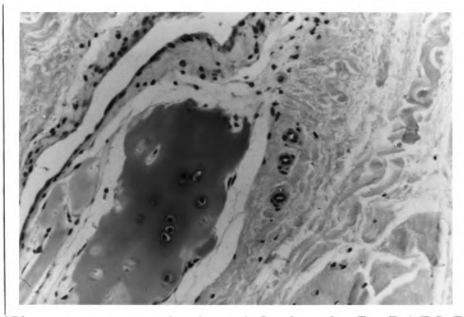

Figure 8. Synovial membrane from the right tibiotarsal synovial sac of a 2.5-year-old Holstein-Friesian cow. Subintimal chondroplasia in degenerative joint disease. H & E. x187.

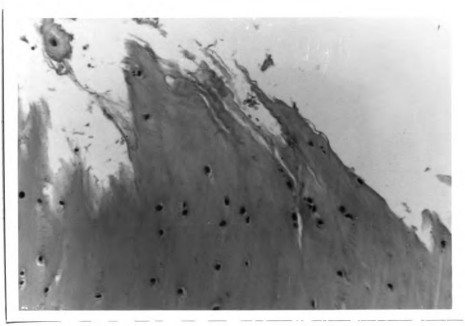

Figure 9. Articular cartilage from the left patella of a 5-year-old Shorthorn bull. Fibrillation and fraying of the articular cartilage in degenerative joint disease. H & E. x187.

of degenerative joint disease.

Articular Cartilages

The articular cartilages in degenerative joint disease evidenced a loss of their normal hyaline appearance, and instead assumed an eosinophilic appearance with H & E stains, appearing "ground-glass-like" in many areas. Cartilaginous fibrillation was evident in both horizontal and tangential planes, giving the stratum superficialis of the articular cartilage a frayed appearance (Figure 9 and 10). Splitting and fibrillation of the articular cartilages in vertical (Figure 11) and tangential planes extended from the stratum superficialis to the stratum calcificatum. Deposition of calcium salts was observed near some of these clefts (Figure 12). Here and there, clusters of chondrocytes were observed in the various strata of the cartilaginous matrix, with lacunae containing chondrocytes near the stratum superficialis and with the intermedius having atrophied.

Traumatic Arthritis

Anamnesis and Clinical Observations

Four tibiotarsal joints, 2 each from a yearling steer and a 5-year-old cow with histories of severe trauma to the affected joints, were investigated.

Both animals had a history of posterior paresis, with subsequent injury to the tarsal joints as a result of repeated attempts to rise. Sensation to pain was present;

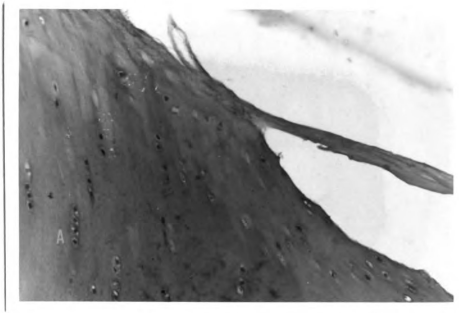

Figure 10. Fibrillation and splitting of the articular cartilage in degenerative joint disease. Chondrocytes (A) have formed into vertical columns. H & E. x187.

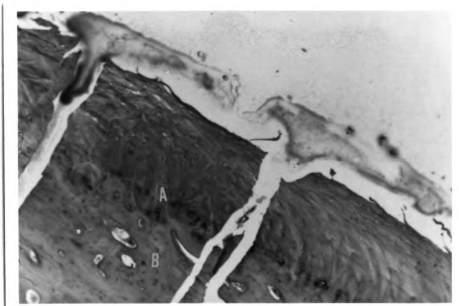

Figure 11. Vertical splitting and fibrillation of the articular cartilage in degenerative joint disease. A thinning of the stratum calcificatum is noted (A). The subchondral bone (B) has become homogeneous, with a loss in the distinct trabecular arrangement of the epiphyseal bone. H & E. x47.

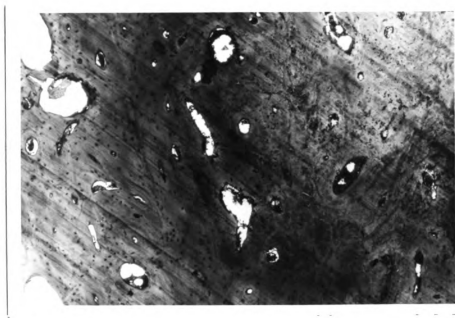

Figure 12. Focal calcification in the subchondral bone in degenerative joint disease. H & E. x47.

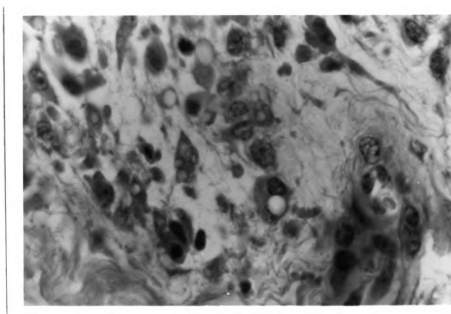

Figure 13. Synovial membrane from the right tibiotarsal synovial sac of a 5-year-old Holstein-Friesian cow affected with traumatic arthritis. Moderate edema and numerous intracytoplasmic vacuoles are noted in this specimen. H & E. x750.

however, attempts to position the hindlimbs met with no success. The cow had been unable to rise immediately following parturition and a diagnosis of postparturient myorrhexis, made on clinical examination, was confirmed on post mortem examination.

Gross Pathologic Observations

Gross pathologic lesions in the joints were confined to the synovial membranes and consisted of scattered foci of subintimal hemorrhages ranging in size from petechiae to areas of suffusion. Occasionally subintimal hematomas were observed. The articular cartilages were unaffected in both animals. The synovial effusions ranged from serosanguineous to hemorrhagic in nature. Periarticular tissues were edematous and bruised, with abrasions on the lateral surfaces of the tarsus and over the point of the tuber calcis.

Histopathologic Observations

Synovial Membranes

The most prominent lesions were those of extensive subintimal hemorrhage and edema. The synovial blood vessels in the stratum synoviale and stratum fibrosum were extremely congested. The synovial intimal cells were hyperplastic and their free surfaces were covered by a fibrinoid material. Occasional vacuoles were observed in the cytoplasm of the synovial intimal cells (Figure 13). Foci of neutrophils and lymphocytes in varying stages of degeneration were scattered

throughout the stratum synoviale; large numbers of lymphocytes, macrophages, and fibroblasts were scattered throughout this layer. Occasionally there was evidence of early foreign body giant cell formation (Figure 14), subintimal foci of calcium deposition (Figure 15), and deposition of hemosiderin (Figure 16). In some areas of the stratum synoviale there was marked infiltration of lymphocytes. The collagenous fibers of the stratum fibrosum had lost much of their distinct fibrillar arrangement, giving the appearance of a homogeneous pink-staining material.

Articular Cartilages

The articular cartilages were not examined microscopically.

Idiopathic Synovitis and Arthritis

Anamnesis and Clinical Observations

Fourteen joints of 8 animals ranging in age from 2.5 months to 5 years were affected with an idiopathic synovitis and arthritis. One steer, 2 cows, and 5 heifers comprised this group. Synovial membrane specimens from 5 of the animals were obtained by punch-biopsy procedures; joint tissue specimens from the 3 remaining animals were obtained at post mortem. The synovial effusions from the joints of all animals in this classification were negative on bacteriologic examination.

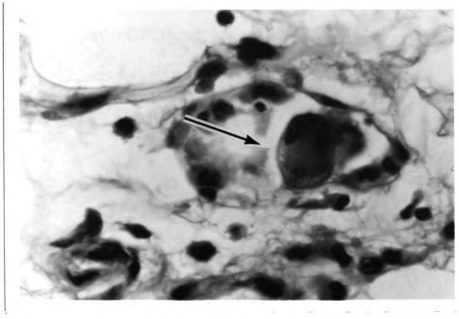

Figure 14. Giant cell (arrow) in the stratum synoviale of the tibiotarsal synovial sac in chronic traumatic arthritis. H & E. x750.

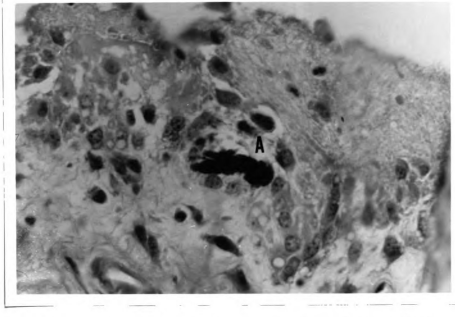

Figure 15. Synovial membrane from the right tibiotarsal synovial sac of a 5-year-old Holstein-Friesian cow. Focal calcium deposition (A) and numerous vacuoles in the cytoplasm of the synovial intimal cells and intercellular spaces surrounding them. H & E. x500.

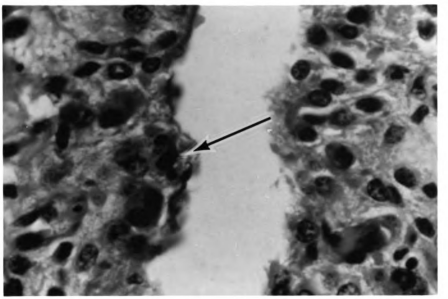

Figure 16. Synovial membrane from the left tibiotarsal synovial sac of a 1-year-old Hereford steer affected with chronic traumatic arthritis. Deposition of hemosiderin (arrow) in the synovial intimal cell layer.

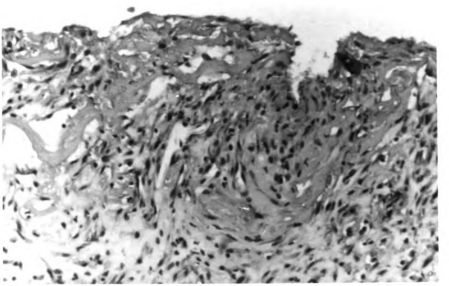

Figure 17. Punch-biopsy specimen from the left tibiotarsal synovial sac of a 5-year-old Holstein-Friesian cow affected with an idiopathic synovitis. Synovial granulation tissue interspersed with neutrophils.

Only limited information could be obtained regarding the anamnesis of cattle affected with an idiopathic synovitis or arthritis. Most of them had a history of being administered systemic antibiotics, which possibly interfered with attempts to culture microorganisms from their synovial effusions. The joints of these animals were characterized by marked distention of their synovial sacs, and in most cases by gross enlargement of their periarticular and articular structures. Acute to subacute idiopathic synovitis or arthritis was evidenced by local heat, arthralgia, reluctance to bear weight on the affected limb, and varying degrees of claudication. Chronic cases were in general limited to distention of the synovial sacs and gross enlargement of the articulation without the associated local heat, arthralgia, and claudication observed in cases of acute to subacute idiopathic synovitis or arthritis.

Gross Pathologic Observations

Gross pathologic observations of joints from which specimens were obtained by joint punch-biopsy were limited to the gross appearance of the synovial effusion and the external appearance of the joint. Joints subjected to post mortem examination varied from a mild hyperemia of the synovial membranes to a fibrinonecrotic exudate that filled the joint cavity. The synovial effusions varied from a pale-yellow, opaque nature to turgid and yellow with considerable

amounts of flocculent debris. Gross lesions of the articular cartilages varied from minimal evidence of erosion to extensive dissolution and erosion of the articular cartilages with associated pannus formation. Periarticular fibrosis was evident in varying degree, dependent upon the severity of the lesions.

Histopathologic Observations

Synovial Membranes

The synovial intimal cells of the stratum synoviale varied from complete absence (Figure 17) to extensive hyperplasia. Villus hyperplasia and hypertrophy were marked in all instances. In many areas villi were covered with a fibrinoid material, while in other areas the villi had undergone extensive hyalinization. Edema and vascular congestion were evident throughout the subintimal layers of the stratum synoviale. Foci of neutrophils interspersed with a few eosinophils were quite pronounced in acute to subacute cases of idiopathic synovitis, whereas follicle-like collections of lymphocytes and perivascular cuffing with lymphocytes were the predominant features in chronic idiopathic synovitis (Figure 18, 19, 20, 21, and 22). The lymphoid follicles were scattered throughout villus and nonvillus portions of the stratum synoviale. One or two small blood vessels were generally found in or near the center of each lymphoid follicle. In some cases, acute to subacute idiopathic synovitis was marked by proliferation of granulation tissue

Figure 18. Synovial villus from the right femoropatellar joint of a 1-year-old Hereford steer. Chronic idiopathic synovitis with a reduction in the number of synovial intimal cells, increased vascularization, and formation of a lymphoid follicle. H & E. x125.

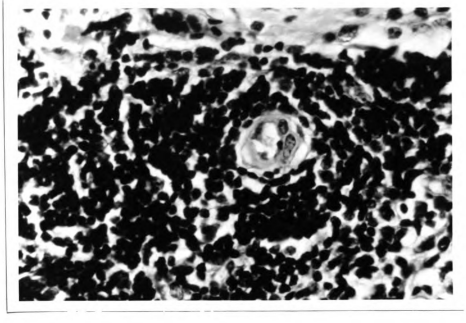

Figure 19. Chronic idiopathic synovitis with follicle-like collection of lymphocytes around a central arteriole. Higher magnification of Figure 18. H & E. x500.

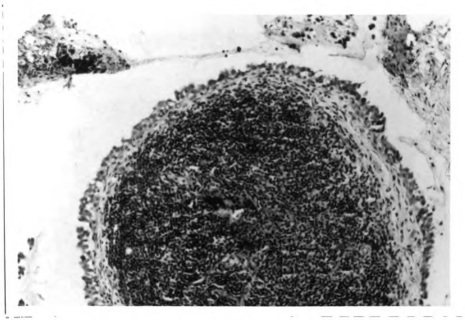

Figure 20. Punch-biopsy specimen from the right tibiotarsal synovial sac of a 10-months-old Guernsey heifer. Chronic idiopathic synovitis with a mild intimal cell hyperplasia, mild subintimal edema, and formation of a lymphoid nodule. H & E. x125.

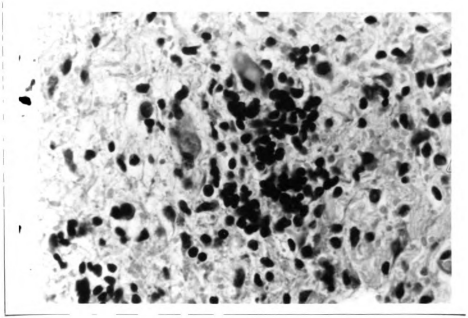

Figure 21. Diffuse lymphocytic infiltration and edema of the stratum synoviale. Higher magnification taken from another area of the section shown in Figure 20. H & E. x500.

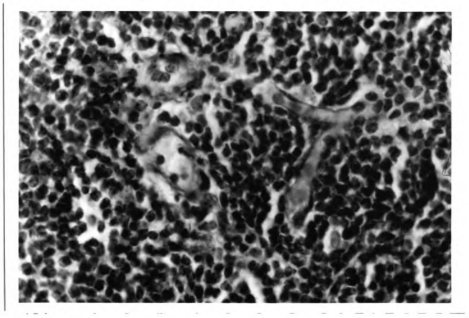

Figure 22. Punch-biopsy specimen from the left tibiotarsal synovial sac of a 5-year-old Holstein-Friesian cow. Perivascular cuffing with lymphocytes in chronic idiopathic synovitis. H & E. x500.

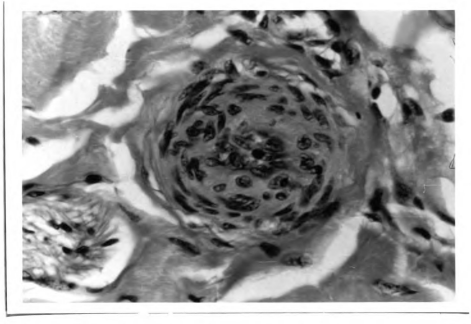

Figure 23. Extreme medial hypertrophy of an artery in the stratum synoviale. Chronic idiopathic synovitis. H & E. x500.

freely interspersed with neutrophils, fibroblasts, and a few macrophages and plasma cells. Arteries and arterioles were observed to have undergone extensive medial hypertrophy (Figure 23). The few remaining synovial intimal cells in acute cases were PAS-negative, whereas in the chronic cases the hyperplastic synovial intimal cells were strongly PAS-positive, particularly near the free border of the intimal layer.

Articular Cartilages

Histopathologic lesions in the articular cartilages varied from a minimal roughening of the stratum superficialis to erosion and loss of the stratum intermedius and stratum radiatus; in some instances erosion reached the stratum calcificatum with exposure of the subchondral bone resulting. Minor lesions consisted primarily of splitting or fibrillation of the articular cartilages and the formation of small clefts in the stratum superficialis and stratum intermedius of the articular cartilages. Chronic lesions were characterized by pannus formation (Figure 24, 25 and 26) in conjunction with subchondral fibrosis (Figure 27 and 28) which was observed to invade the stratum calcificatum. Osteoclasts were often observed adjacent to bony spicules in areas of subchondral fibrosis, as were foci of polymorphonuclear neutrophils interspersed with a few eosinophils. The articular cartilage was observed to lose its normal characteristic hyaline appearance and instead take on an eosinophilic

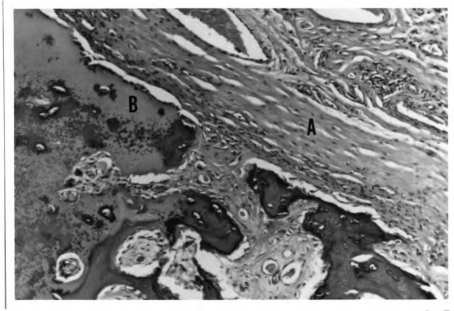

Figure 24. Pannus formation (A) has destroyed the articular cartilage and subchondral bone. Calcification of the bony trabeculae of the epiphysis is taking place (B). Chronic idiopathic arthritis. H & E. x125.

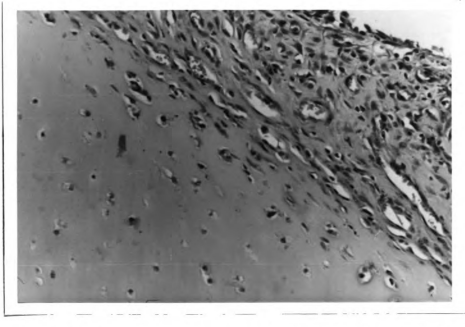

Figure 25. Early pannus invasion of the articular cartilage in chronic idiopathic arthritis. H & E. x125.

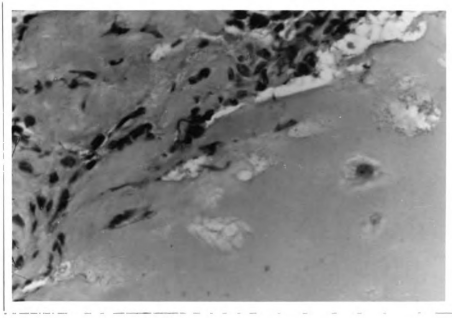

Figure 26. Dissolution of the articular cartilage by pannus formation in chronic idiopathic arthritis. Chondrocytes have disappeared from their lacunae. H & E. x500.

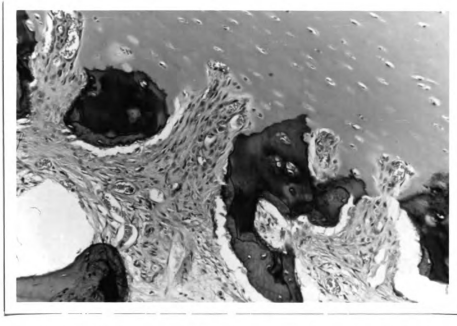

Figure 27. Invasion of the articular cartilage by subchondral granulation tissue in idiopathic arthritis. H & E. x500.

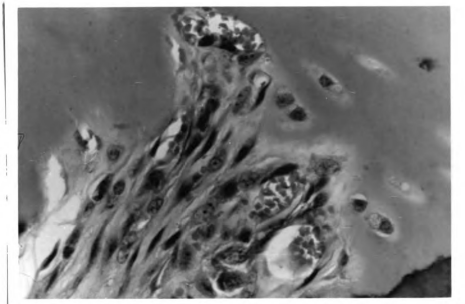

Figure 28. Granulation tissue invading the articular cartilage. Higher magnification of Figure 27. H & E. x500.

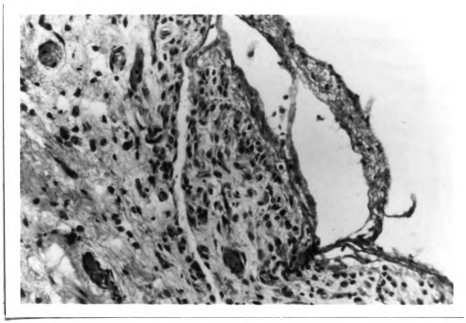

Figure 29. Synovial membrane from the femoropatellar joint of a 2-day-old Aberdeen-Angus heifer. Note the loss of synovial intimal cells and degeneration of the stratum synoviale. Escherichia coli was isolated from the synovial effusion. H & E. x187.

appearance with H & E stains. Foci of calcium deposition were observed on the surface of the articular cartilage as well as in areas of subchondral fibrosis in cases of chronic idiopathic arthritis.

Infectious Arthritis

Anamnesis and Clinical Observations

Eighteen joints of 7 animals ranging in age from 2 days to 3 years, with a mean age of 1.9 $\pm$ 0.4 years, were investigated. A variety of microorganisms was isolated from the synovial effusions of the various joints (Table 44).

Polyarthritis in young calves was attributed to metastasis of bacteria from neonatal infections of the umbilicus. These animals in general had elevated body temperature and showed signs of dehydration, anorexia, and diarrhea. The joints were inflamed, swollen, and on palpation the calves elicited a response as to pain. All synovial sacs were grossly distended and, in many instances, the bones that composed the articulation were grossly enlarged. Varying degrees of claudication were in evidence when the animal was forced to move. Joints of older animals became infected following a penetrating wound to the joint cavity or as the result of spread of infection to the joint cavity from an area adjacent to the particular articulation (Figure 1). The joints of older cattle were found to have essentially the same lesions as those of young calves.

TABLE 44. Pathologic Classification and Identification of Microorganisms Isolated from the Joints of Cattle with Infectious Arthritis Due to Bacteria

No.	Breed	Age	Sex	Joint(s)	Pathologic Classification*		
					Duration of Inflammation	Mode of Infection	Microorganism(s)
1	Holstein-Friesian	13 days	Heifer	Intercarpal Tibiotarsal	Subacute	Secondary	Streptococcus viridans
2	Holstein-Friesian	3 yrs.	Bull	Tibiotarsal	Chronic	Secondary	Corynebacterium pyogenes
3	Holstein-Friesian	6 days	Heifer	Radiocarpal Tibiotarsal Coxofemoral	Acute	Tertiary	Streptococcus viridans
4	Abderdeen-Angus	2 days	Heifer	Radiocarpal Intercarpal Coxofemoral Femoropatellar Tibiotarsal	Acute	Tertiary	Escherichia coli
5	Holstein-Friesian	2 wks.	Heifer	Tibiotarsal	Subacute	Tertiary	Corynebacterium pyogenes Streptococcus fecalis
6	Holstein-Friesian	8 mo.	Steer	Femoropatellar	Chronic	Primary	Corynebacterium pyogenes
7	Holstein-Friesian	17 days	Heifer	Radiocarpal Intercarpal Carpometacarpal Femoropatellar Tibiotarsal	Subacute	Tertiary	Streptococcus viridans

*Infectious arthritis was classified on the bases of: (1) duration of the infection (acute, subacute, or chronic); (2) mode of joint infection (primary = penetration of a foreign object into the joint cavity; secondary = extension from an area of infection adjacent to the joint cavity; tertiary = associated with a septicemia or metastasis from an area of infection in some other part of the body not adjacent to the joint cavity; and (3) microorganism(s) isolated from the synovial effusion.

The signs of dehydration, emaciation, and diarrhea observed in calves did not occur in the older cattle in this group.

Gross Pathologic Observations

Calves affected with a specific infectious arthritis had enlarged joints containing excessive synovial effusions that appeared turbid and yellow, with considerable amounts of flocculent debris. The joint capsules were thickened, with marked evidence of periarticular fibrosis. The synovial membranes appeared hyperemic and in many areas were covered with fibrinonecrotic exudates, which were more pronounced in joint infections due to Corynebacterium pyogenes than those due to Streptococcus viridans, Streptococcus fecalis, or Escherichia coli. The articular cartilages in subacute infectious arthritis had undergone early erosion and dissolution, whereas in chronic infectious arthritis, particularly those cases due to C. pyogenes, the articular cartilages were often eroded in some areas to the point where denuded subchondral bone was exposed. Joints of calves and older animals affected with chronic septic arthritis due to C. pyogenes contained inspissated fibrinopurulent casts that conformed to the confines or shape of the joint cavity and articular cartilages. Removal of fibrinopurulent casts from the synovial membranes revealed raw denuded hemorrhagic surfaces, with evidence of extensive capillary proliferation of the type seen associated with exuberant granulation tissue.

Histopathologic Observations

Synovial Membranes

Histopathologic lesions for joints affected with septic arthritis were observed to vary with the virulence of the microorganism for joint tissues and the duration of the disease. Joints infected with C. pyogenes were observed to undergo a more severe inflammatory response than those infected with S. viridans, S. fecalis, or E. coli.

The stratum synoviale was devoid of synovial intimal cells on the majority of the villi (Figure 29 and 30) in the few areas where synovial intimal cells remained the free borders of the cytoplasm appeared to be frayed or fimbriated in appearance. The cytoplasm of these remaining cells had undergone hypertrophy, with an increased staining reaction of their contents. Underlying the few remaining synovial intimal cells and in areas devoid of these cells, proliferating granulation tissue was observed (Figure 31 and 32). Large numbers of neutrophils and a lesser number of eosinophils were scattered throughout this tissue (Figure 33 and 34) which included lymphocytes, mast cells, macrophages, and numerous fibroblasts. Erythrocytes were seen scattered throughout areas of granulation while some areas were severely congested (Figure 35). Foci of caseous or caseo-calcareous material were invariably observed in juxtaposition to the free surface of the granulation tissue or immediately

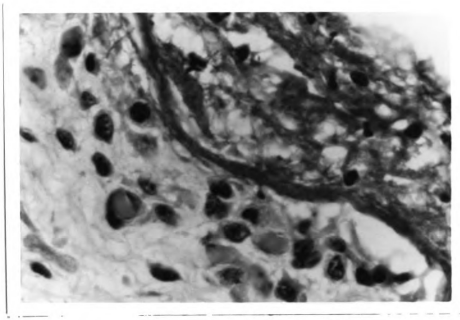

Figure 30. Synovial intimal cells have been replaced by a fibrinous exudate. Higher magnification of Figure 29. H & E. x750.

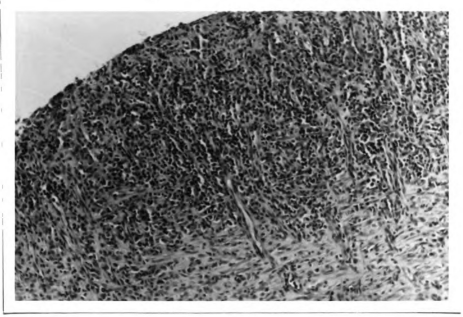

Figure 31. Synovial membrane from the left tibiotarsal joint of a 2-week-old Holstein-Friesian heifer. The stratum synoviale has been replaced by granulation tissue. Corynebacterium pyogenes was isolated from the synovial effusion. H & E. x125.

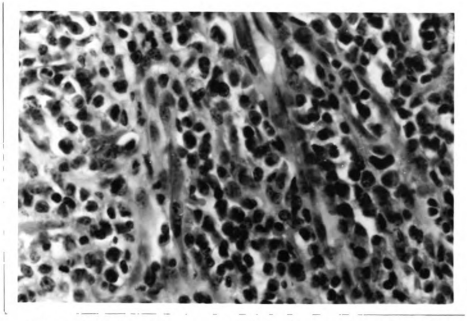

Figure 32. Proliferating capillaries are surrounded by lymphocytes, macrophages, and a few neutrophils. Higher magnification of granulation tissue shown in Figure 31. H & E. x500.

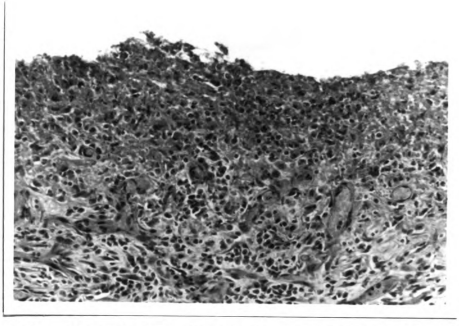

Figure 33. Granulation tissue and a necrotic debris have completely replaced the articular cartilage and subchondral bone of the proximal end of the tibiotarsal bone. From animal shown in Figure 31. H & E. x125.

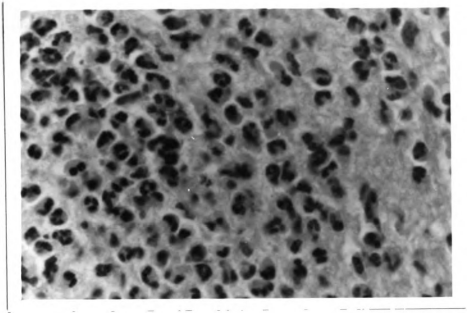

Figure 34. Punch-biopsy specimen from the left tibiotarsal synovial sac of a 13-day-old Holstein-Friesian heifer. Massive invasion of neutrophils in the synovial membrane. Streptococcus viridans isolated from the synovial effusion. H & E. x500.

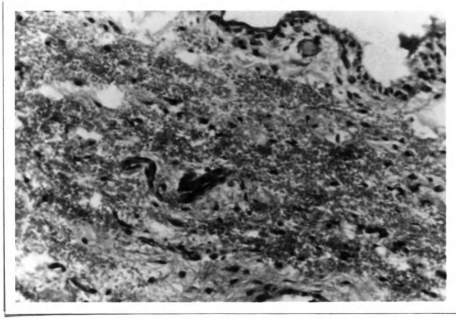

Figure 35. Subintimal hemorrhage and edema in the stratum synoviale of the right femoropatellar joint. From animal shown in Figure 29. H & E. x125.

below the synovial intimal cells. Edema, vascular proliferation and congestion were in evidence. Many arteries had undergone medial hypertrophy (Figure 38). Smaller arteries and arterioles showed evidence of perivascular cuffing with lymphocytes, interspersed with an occasional macrophage. Thrombi were frequently observed (Figure 36 and 37). The PAS stain revealed a positive reaction in the cytoplasm of numerous fibroblasts, undifferentiated mesenchymal cells, and mast cells. Considerable amounts of PAS-positive material were noted in the cytoplasm of numerous macrophages.

Joints infected with microorganisms other than C. pyogenes manifested a severe inflammatory response. Loss of synovial intimal cells was not as great; in some cases there was, in addition to villus hyperplasia and hypertrophy, hyperplasia of the synovial intimal cells with a tendency in some areas for palisading. The free surface of the stratum synoviale was generally covered with a fibrinous material or the synovial intimal cells had undergone a fibrinoid degeneration; in both instances, fibrinoid material contained enmeshed neutrophils. Compacted masses of basophilic reticular fibers were frequently observed in a subintimal location.

The stratum fibrosum was greatly thickened in joints infected with microorganisms; this was particularly apparent in joints from which C. pyogenes was isolated. Extensive

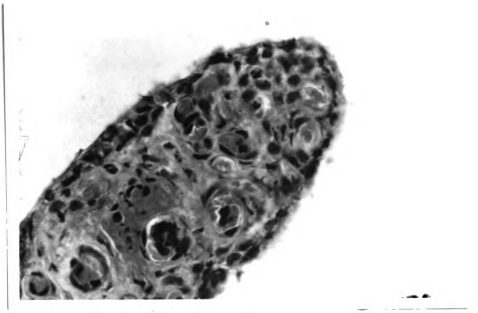

Figure 36. Synovial villus from the left coxofemoral joint of a 6-day-old Holstein-Friesian bull. Note the thrombi in the vessels. Streptococcus viridans was isolated from the synovial effusion. H & E. x125.

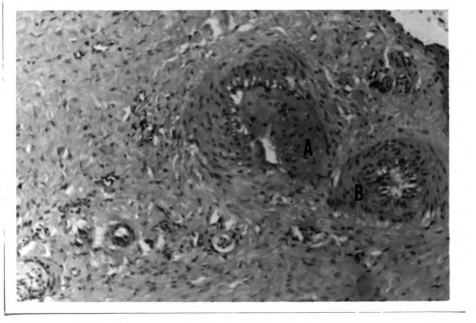

Figure 37. Organized thrombus (A) in a subsynovial artery. Medial hypertrophy may be seen in an adjacent artery (B). From animal shown in Figure 31. H & E. x125.

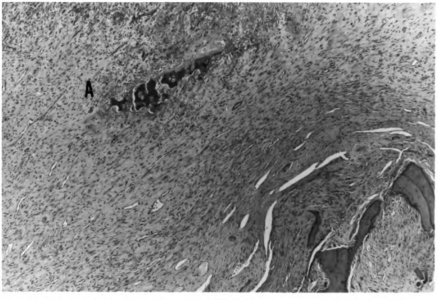

Figure 38. Subchondral fibrosis in the area of the epiphysis. A calcifying bony spicule may be seen (A). From animal shown in Figure 31. H & E. x47.

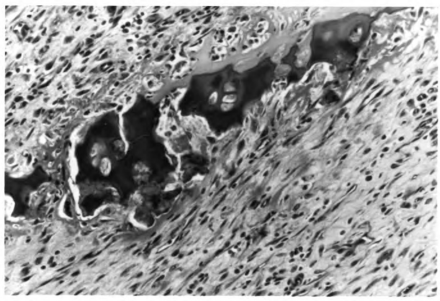

Figure 39. Calcifying bony spicule in an area of subchondral fibrosis. Higher magnification of Figure 38. H & E. x187.

medial hypertrophy of arteries in this layer was quite pronounced (Figure 37).

Articular Cartilages

Histopathologic lesions in the articular cartilages were observed to vary with the virulence of the microorganisms and the duration of the infection. Severe destruction and loss of articular cartilage was a consistent finding in joints infected with C. pyogenes. The salient features were those of horizontal and vertical splitting, flaking, deposition of calcareous material, vertical clefts with invasion by granulation tissue, and extensive pannus formation (Figure 38 and 39). Pannus formation was initiated at the perichondral margins of the joint and extended over the articular cartilages, resulting in their erosion and eventual dissolution. Foci of caseous to caseo-calcareous material were frequently observed at the margins of the articular cartilages, often associated with extensive subchondral and epiphyseal fibrosis, which penetrated the cartilaginous matrix, resulting in its ultimate destruction. Frequently, numerous neutrophils and eosinophils were scattered throughout the fibrous tissue and foci of neutrophils were in the matrix of the articular cartilage. Articular cartilages had lost their normal hyaline appearance and, instead, taken on a pink-staining, osteoid appearance with H & E stains (Figure 40 and 41). Osteoclasts were occasionally observed

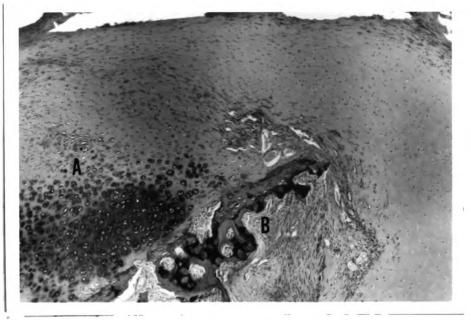

Figure 40. Degenerating articular cartilage with a focus of chondroplasia (A). The cartilaginous matrix has taken on a homogeneous pink-staining appearance. Subchondral bone is undergoing calcification and invasion by fibrous tissue (B). Section from joint of animal shown in Figure 31. H & E. x47.

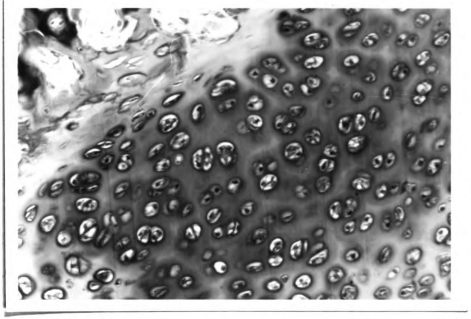

Figure 41. Focus of chondrocytes in degenerating articular cartilage. Higher magnification of area in Figure 40. H & E. x187.

adjacent to the bony spicules found in the juxtachondral and juxtaepiphyseal areas of the bones making up the articulation. Giant cells were generally found in areas of subchondral fibrosis (Figure 42).

Joints infected with S. viridans, S. fecalis, and E. coli did not undergo as severe destruction of articular cartilages as observed in joint infections due to C. pyogenes. Early dissolution of articular cartilages was observed, often in association with the formation of vascular channels, in the stratum superficialis and stratum intermedius. Intrachondral blood vessels were congested and often contained small organized thrombi. Frequently perivascular fibrosis of these vessels was a consistent finding. Such areas of vascularization and fibrosis often contained numerous neutrophils with occasional lymphocytes and macrophages scattered throughout the fibrous matrix.

Polyarthritis Associated with Primary Systemic Infections

Anamnesis and Clinical Observations

Thirty joints of 3 heifers and 5 bulls ranging in age from 4 days to 1 year, with a mean age of 0.2 ± 0.1 year, were affected with a nonspecific arthritis secondary to a primary systemic infection (Table 45). The joints of these animals proved to be negative on culture for bacterial growth.

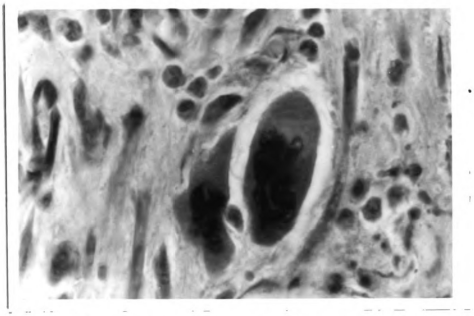

Figure 42. Giant cells in the subchondral fibrous tissue of the proximal end of the tibiotarsal bone. Section from the joint of animal shown in Figure 31. H & E. x750.

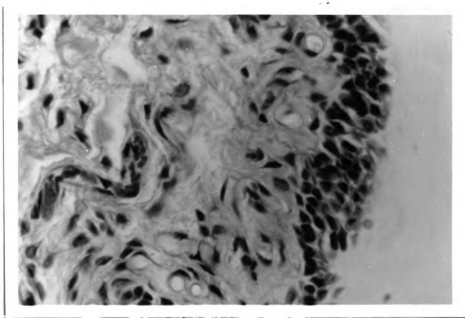

Figure 43. Synovial membrane from the left femoropatellar joint of a 1-year-old Holstein-Friesian heifer. Synovial intimal cell hyperplasia and edema. H & E. x500.

TABLE 45. Polyarthritis Associated with Primary Systemic Infections in Cattle

No.	Breed	Age	Sex	Pathologic Diagnosis*	Organ(s)	Microorganism(s) Isolated
1	Hereford	1.5 mos.	Bull	Salmonellosis	Kidney, Small Intestine	Salmonella spp.
2	Holstein-Friesian	4 days	Bull	Enteritis	Small Intestine	Escherichia coli
3	Holstein-Friesian	1 yr.	Heifer	Enteritis	Small Intestine	Proteus mirabilis Paracolobactrum spp.
4	Holstein-Friesian	2 mos.	Heifer	Pneumonia	Lung, Thymus, Heart, Small Intestine	Escherichia coli Bacterium anitratum Proteus spp.
5	Hereford	2 wks.	Bull	Omphalophlebitis	Umbilicus	Proteus spp.
6	Holstein-Friesian	1 mo.	Heifer	Pneumonia	Lung, Spleen, Liver, Kidney, Small Intestine	Streptococcus viridans Proteus rettgari
7	Holstein-Friesian	3 wks.	Bull	Salmonellosis	Small Intestine	Salmonella spp.
8	Holstein-Friesian	1 wk.	Bull	Meningio-encephalitis	Brain, Spleen, Liver, Kidney	Escherichia coli

*Pathologic diagnosis was made on the basis of gross, microscopic, hematologic, and bacteriologic findings.

Joints of young cattle affected with polyarthritis secondary to primary systemic infections showed marked evidence of increased synovial effusion, heat, and pain on palpation of the affected joint or joints. On locomotion, these animals showed signs of arthralgia, variable degrees of claudication and, in many instances, reluctance to move. Systemic infections were so severe in some cases that the animals were in lateral recumbency prior to euthanasia for post-mortem examination.

Gross Pathologic Observations

Gross pathologic lesions in the joints varied from mild to severe hyperemia of the synovial membranes, with varying degrees of villus hyperplasia and hypertrophy. Gross appearance of the synovial fluid varied from pale-yellow and opaque, with lesser amounts of flocculent material, to turbid and yellow, with large amounts of flocculent material. The articular cartilages had undergone early degenerative changes, as evidenced by loss of their smooth hyaline appearance and by minor erosions. Early articular pannus formation was observed at the perichondral margins of the articular cartilages.

Histopathologic Observations

Synovial Membranes

There was marked evidence of villus hyperplasia and hypertrophy, primarily of the pedunculated type. Synovial

intimal cell (Figure 43) hyperplasia was present, with many of the synovial intimal cells appearing fibroblastic with fimbriation of their free borders. Fibrinoid degeneration was observed in many areas, often involving the entire intimal cell layer, in association with subintimal fibrosis. In other areas of the synovial membrane, a fibrinopurulent exudate was adhered to the surface of the synovial intimal cells. Subsynovial edema and congestion were evident; some areas of the subsynovium were hyperemic with evidence of hemorrhage into the surrounding tissue. Invariably, thrombi (Figure 44) were noted in the vessels of the stratum synoviale with an increased ratio of neutrophils to erythrocytes. Subintimal capillary hyperplasia and congestion were pronounced. Scattered neutrophils and mixed foci of lymphocytes, neutrophils, and macrophages were routinely observed scattered throughout the stratum synoviale (Figure 45). Foci of subsynovial compact masses of intensely basophilic reticular fibers were frequently scattered throughout this layer. Precipitated calcium salts were occasionally observed on the surface of the synovial intimal cells, between their cytoplasmic processes, or in a subsynovial intimal cell position. An occasional mast cell was observed in the deep layers of the stratum synoviale.

The stratum fibrosum in general was markedly thickened and its arteries had undergone extensive hypertrophy

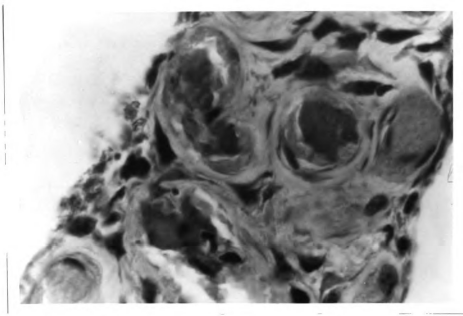

Figure 44. Synovial villus from the right carpometacarpal joint of a 6-week-old Hereford bull. Note the thrombi in the capillaries. Salmonella spp. isolated from the kidney and small intestine. H & E. x750.

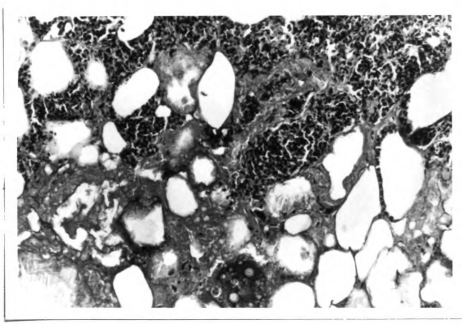

Figure 45. Degenerating inflammatory cells and adipose tissue in the subsynovium. Section from the right tibiotarsal joint of the animal involved in Figure 44. H & E. x187.

of their medial layers in conjunction with an increased perivascular fibrosis.

Articular Cartilages

The articular cartilages were roughened inconsistently over their surfaces, with areas of early degeneration and dissolution. Longitudinal splitting and vertical clefts were observed in the various strata of the articular cartilages of some joints. Occasional foci of calcium salts were observed on the surface of the articular cartilages or within the stratum superficialis or stratum intermedium (Figure 46). There was early pannus development at the perichondral margins and extending over the surface of the articular cartilages (Figure 47). This tissue was composed predominantly of a cell type which appeared similar to synovial intimal cells, whereas in other pannus formations the cells were fibroblastic. Chrondral vascularization with congestion of these vessels was a constant feature. Thrombi were often observed in the lumens of the vessels (Figure 48). Subchondral and epiphyseal fibrosis were observed in many cases, with early invasion of fibrous tissue into the matrix of the articular cartilages.

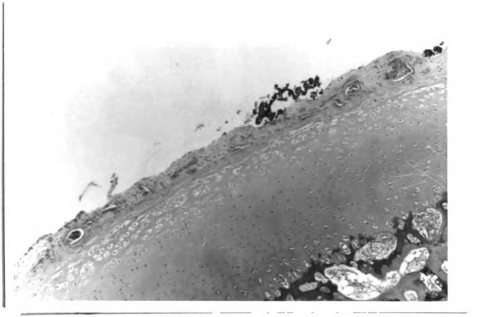

Figure 46. Pannus formation on the articular surface of the proximal trochlea of the tibiotarsal bone. Calcium deposition is seen on the surface of the pannus. Blood vessels in the pannus contain thrombi. Lacunae of the chondrocytes in the stratum superficialis are undergoing hydropic degeneration. Section from the right tibiotarsal joint of the animal represented in Figure 44. H & E. x47.

Figure 47. Calcium deposition on the surface of the pannus. Higher magnification of Figure 46. H & E. x47.

Figure 48. Thrombus in a pannus vessel (A). Note the hydropic degeneration of the chondrocytes (B). Higher magnification from Figure 46. H & E. x187.

V. DISCUSSION

Synovial Fluid Analyses

Group I--Synovial Effusions that Resemble Normal Synovial Fluids

Synovial effusions from cattle affected with either primary or secondary degenerative joint disease were indistinguishable from each other either grossly or following laboratory analyses. Ropes and Bauer (1953) made similar observations in degenerative joint disease of man.

Cattle affected with tarsal hydrarthrosis had synovial effusions that grossly appeared normal, but existed in excessive quantities. Tarsal hydrarthrosis in cattle resembled its human counterpart only in that excessive synovial effusions are characteristic of both conditions. Synovial effusions from idiopathic intermittent hydrarthrosis in man are exudative in nature rather than transudative as is the case with cattle. In man, hydrarthrosis of the knee joint is idiopathic in nature and characterized by periodic exacerbations and remissions (Porter and Lanergan, 1932)

Effusions from cattle affected with acute or chronic traumatic arthritis, with the exception of their high erythrocyte and leukocyte counts, were not remarkably different

from the effusions of degenerative joint disease or tarsal hydrarthrosis. Xanthochromia was more pronounced in synovial effusions due to trauma of a chronic nature.

The relative viscosity and mucinous precipitate of synovial effusions from the tibiotarsal joints of cattle affected with degenerative joint disease and acute traumatic arthritis did not vary markedly from the normal limits for this joint. In spite of increased effusions which could alter the normal ratio of hyaluronic acid to unit volume, joints were apparently able to maintain production of sufficient quantities of hyaluronic acid. Synovial effusions from the tibiotarsal joints of cattle affected with chronic traumatic arthritis and tarsal hydrarthrosis had a lower relative viscosity than that of normal synovial fluid. The reduced relative viscosity of synovial effusions from the tibiotarsal joints of cattle affected with chronic traumatic arthritis cannot be attributed entirely to a decrease in the ratio of hyaluronic acid to unit volume, but rather to a reduction in the mean degree of polymerization of the hyaluronic acid molecules as demonstrated by tests for quality of mucinous precipitate. The low relative viscosity and high volume of synovial fluid obtained from the joints of cattle affected with tarsal hydrarthrosis suggested a reduced ratio of hyaluronic acid to unit volume, rather than a reduction in the mean degree of polysaccharide polymerization, particularly in view of the large number of normal mucinous precipitates

(60%) recorded and the small unit size of the precipitate in relation to mucinous precipitates from normal synovial fluids.

The synovial fluid-blood sugar ratio for cattle affected with degenerative joint disease and tarsal hydrarthrosis was 1:1. This indicated that passage of sugar across the blood-joint barrier and rate of utilization by the synovial tissues, articular cartilages, and synovial fluid was in a state of dynamic equilibrium.

Sugar levels for synovial effusions from joints affected with acute or chronic traumatic arthritis markedly exceeded their respective blood sugar levels. This finding in cattle was contrary to that reported for man, in that synovial fluid sugar levels in man are reduced due to an increased glycolytic enzyme activity associated with high numbers of erythrocytes in traumatic synovial effusions (Ropes and Bauer, 1953). The elevated sugar levels in synovial effusions from traumatized joints of cattle (synovial fluid-blood sugar ratio of 1.1:1) were attributed to the transudative nature of the effusions, i.e., the plasma fraction of a synovial transudate contains a higher sugar level than that of synovial fluid or whole blood (Ratcliff et al., 1948; and Van Pelt and Conner, 1963c). The erythrocytes in traumatic effusions were either not in sufficient numbers to produce any appreciable glycolysis or their glycolytic activity was counteracted by a rapid and excessive transudation of plasma across the blood-joint barrier.

The alkaline phosphatase (ALP) activity of synovial effusions from cattle affected with degenerative joint disease, and acute and chronic traumatic arthritis exceeded the ALP activity of their serum counterpart. No statistically significant difference was encountered between synovial fluid and serum ALP activity for cattle affected with tarsal hydrarthrosis. In this investigation, the ALP activity of synovial effusions from cattle affected with degenerative joint disease never attained the mean values reported for normal cattle. Cattle affected with acute and chronic traumatic arthritis had synovial fluid ALP values higher than those of cattle affected with degenerative joint disease; however, the mean synovial fluid ALP activity never attained the mean levels reported for normal cattle. Synovial fluid from cattle affected with tarsal hydrarthrosis proved to have the lowest ALP activity in Group I synovial effusions.

Synovial fluid lactic dehydrogenase (LDH) activity for synovial effusions from cattle affected with degenerative joint disease and tarsal hydrarthrosis were similar. The LDH values for synovial effusions in both conditions exceeded slightly the mean normal value of 209 $\pm$ 22 LDH units/ml. of synovial fluid determined by Van Pelt (1964) for normal dairy cattle. The LDH activity of synovial effusions from cattle affected with degenerative joint disease and tarsal hydrarthrosis was significantly lower than their

serum LDH values. In all cases, serum LDH values were less than the normal serum value of 3.5×10^3 LDH units/ml. reported by Cardeilhac and Cardeilhac (1963).

The mean synovial fluid glutamic oxalacetic transaminase (SY-GOT) activity for synovial effusions from the joints of cattle affected with degenerative joint disease and tarsal hydrarthrosis was less than the mean normal SY-GOT values for cattle. However, individual SY-GOT values occasionally exceeded mean normal values. The mean serum glutamic oxalacetic transaminase (S-GOT) activity for cattle affected with degenerative joint disease and tarsal hydrarthrosis was within the normal limits reported by Cornelius et al. (1959).

Synovial effusions from the joints of cattle affected with degenerative joint disease and tarsal hydrarthrosis had synovial fluid glutamic pyruvic transaminase (SY-GPT) activity values less than the SY-GPT activity for normal cattle. This finding would suggest an absence of any inflammatory response in the joint or the possibility of a dilution factor in view of the elevated volume of the effusions encountered. Serum glutamic pyruvic transaminase (S-GPT) activity values for these cattle were within the normal limits reported by Cornelius et al. (1959).

The mean leukocyte counts for synovial effusions from cattle affected with degenerative joint disease, with the exception of the intercarpal joints, exceeded synovial

fluid leukocyte values for normal cattle. This finding suggested a cellular response to the degenerative processes taking place within the joint, particularly in view of the fact that the cytoplasm of monocytes and macrophages were frequently noted to contain phagocytized material. The erythrocytes in synovial effusions from cattle affected with degenerative joint disease were attributed to struggling on the part of the animal at the time of arthrocentesis.

Synovial effusions from cattle affected with acute traumatic arthritis had higher total leukocyte counts than effusions from joints affected with chronic traumatic arthritis. The acute status of synovial effusions from cattle affected with acute traumatic arthritis was demonstrated by the high absolute number of neutrophils in contrast to other cell types. In view of the predominately hemorrhagic nature of acutely traumatized joints, it is apparent that at least in part, a large proportion of the leukocytes were attributed to their passage into the joint at the time hemorrhage occurred. Low grade hemorrhage or periods of intermittent hemorrhage accounted for in part, the elevated leukocyte counts in joints subjected to chronic trauma.

Synovial effusions from cattle affected with tarsal hydrarthrosis had lower total erythrocyte and leukocyte counts than joints affected with degenerative joint disease, or acute or chronic traumatic arthritis.

Group II--Intermediate Synovial Effusions

Most synovial effusions from joints affected with idiopathic arthritis were exudative in nature (82.3%). Serosanguineous effusions were encountered in one tibiotarsal and two femoropatellar joints. Failure to culture bacteria from synovial effusions in Group II was attributed to two possible factors: (1) administration of systemic antibiotics or sulfonamides by the owner or attending veterinarian prior to arthrocentesis; and (2) absence of bacteria from the joint effusion at the particular time synovial specimens were aspirated. No attempt was made to culture for Mycoplasma spp. or viruses from synovial effusions in this group.

A tendency to clot rapidly was characteristic of Group II synovial effusions, hence the use of a suitable anticoagulant for extensive studies of unclotted synovial fluid.

The volume of synovial effusions in this group were in excess of normal, particularly effusions obtained from the tibiotarsal joint. The lowered relative viscosity of synovial effusions from cattle affected with an idiopathic arthritis were considered a reflection of the reduced polymerization and quantity of the hyaluronic acid portion of the effusions as shown by tests for mucinous precipitate.

Synovial fluid sugar levels for cattle affected with an idiopathic arthritis were lower than their corresponding

blood sugar levels by a mean difference of 30.53 ± 8.14 mg./100 ml. This amounted to a synovial fluid sugar reduction of 32.7%, resulting in a synovial fluid-blood sugar ratio of 0.7:1. Decreased sugar levels in synovial effusions from joints affected with an idiopathic arthritis were attributed to several factors. One such factor was the presence of a high absolute number of neutrophils, the cytoplasm of which contains glycolytic enzymes (Hubbard and Porter, 1943). Other factors included decreased passage of sugar across the blood-joint barrier (Ropes et al., 1960), and increased utilization of sugar by inflamed and proliferated synovial tissues (Ropes and Bauer, 1953).

The alkaline phosphatase (ALP) activity of synovial effusions from the joints of cattle affected with an idiopathic arthritis were significantly higher than their corresponding serum ALP values and higher than that of normal synovial fluid. In view of the elevated levels of ALP activity in synovial effusions from joints affected with an idiopathic arthritis, it is postulated that this enzyme may be derived from two sources: (1) the high number of neutrophils; and (2) joint tissues, the inflamed synovial membrane, articular cartilages, and subchondral bone.

Synovial fluid lactic dehydrogenase (LDH) activity was highly elevated in contrast to normal synovial fluid LDH activity.

Synovial fluid glutamic oxalacetic transaminase (SY-GOT) activity almost paralleled that of its serum glutamic oxalacetic transaminase (S-GOT) activity, but exceeded normal SY-GOT activity for bovine synovial fluid. Synovial fluid glutamic pyruvic transaminase (SY-GPT) activity was 41% greater than its respective serum glutamic pyruvic transaminase (S-GPT) activity. Normal SY-GPT activity for cattle is approximately 56.4% lower than its corresponding S-GPT activity as determined by Van Pelt (1964).

The exudative nature of synovial effusions from the joints of cattle affected with an idiopathic arthritis was confirmed by the high total leukocyte counts and high absolute number of neutrophils.

Group III--Septic Synovial Effusions

Synovial effusions from the joints of cattle affected with infectious arthritis due to bacterial organisms were predominantly (88.8%) exudative in nature. Joint effusions of a serosanguineous nature were encountered in only two tibiotarsal joints.

The reaction to infection by bacteria on the part of the various joints varied markedly, depending on the degree and duration of the infection, and the joint or joints in question. Clinically, symptoms ranged from arthralgia in the absence of signs of inflammation to arthritis of varying degrees of severity. Infectious arthritis produced signs of

hyperarthresthesia upon palpation of the affected joint or joints, arthrocele due to excess synovial effusion, and attendant arthrosteitis, hyperarthrothermia, and varying degrees of claudication. Persistent arthrogryposis was noted in severe cases of infectious arthritis.

Infectious arthritis due to Corynebacterium pyogenes produced lesions of an extremely severe nature in contrast to infectious arthritis produced by other bacterial organisms.

Synovial effusions from joints affected with infectious arthritis exceeded normal volume and clotted rapidly unless an anticoagulant was employed.

Relative viscosity was reduced and the number or poorer grades of mucinous precipitate was high. Ropes and Bauer (1953) have pointed out that the concentration of mucin in joint diseases is related to the type, severity, and duration of the disease and the duration of the synovial effusion. The lowest concentrations of mucin were found in severe cases of infectious arthritis or rheumatoid arthritis. At this time it is suggested that the reduced relative viscosity and poor quality of hyaluronic acid encountered in infectious synovial effusions was due to the severity of the joint inflammation resulting in a depolymerization of the hyaluronic acid and failure on the part of the synovial intimal cells to produce adequate amounts of mucin or mucin in a highly polymerized state.

The synovial fluid-blood sugar ratio of 0.5:1 for cattle affected with infectious arthritis was considerably altered from the normal 1:1 ratio (Van Pelt and Conner, 1963c). Blood sugar levels exceeded synovial fluid sugar levels by a mean difference of 32.89 $\pm$ 8.10 mg./100 ml.

The alkaline phosphatase (ALP) activity of synovial effusions from joints of cattle affected with infectious arthritis was significantly higher than the corresponding serum value, but mean synovial fluid ALP activity for Group III animals never attained the level determined for normal dairy cattle. Synovial effusions from individual joints, however, attained extremely high ALP values.

Synovial effusions from cattle in this group reflected their exudative nature by the high total leukocyte counts and the high absolute number of neutrophils. The severity of infectious arthritis was manifested in the peripheral blood by a leukocytosis, with a marked increase in the number and immaturity of neutrophils (particularly an increase in the nonsegmented forms in relation to segmented forms).

Gross and Histopathologic Observations

Degenerative Joint Disease

Degenerative joint disease of man and animals is generally associated with advanced age. In this investigation, two Holstein-Friesian cows, 2 and 2.5 years of age respectively, were affected with secondary degenerative joint disease of the tibiotarsal joint. Secondary degenerative joint disease in younger cattle was attributed to joint conformation defects resulting in acceleration of the processes that lead to degeneration of joint tissues, particularly the articular cartilages. In older cattle affected with primary degenerative joint disease, the disease was considered a manifestation of the normal aging processes or in some cases an unexplained acceleration of these processes.

Traumatic Arthritis

Traumatic arthritis did not conform to a clearly defined uniform or typical condition. Collins (1949) employed the term to denote either an arthritis directly resulting from an intracapsular fracture or penetrating wound, or a chronic arthritis brought about by a traumatically displaced loose body or injured meniscus.

The gross pathologic lesions observed in the two animals with chronic traumatic arthritis were confined primarily to the periarticular tissues of the affected joints

and the synovial membranes. There was no evidence of detachment, splitting, or laceration of the articular cartilages, articular fractures, or compression fractures of the bones.

Microscopically, a mild synovitis in conjunction with extensive subintimal hemorrhage and edema were the salient features.

Idiopathic Synovitis and Arthritis

The joints of cattle affected with an idiopathic synovitis or arthritis appeared grossly and microscopically similar to those of cattle affected with a specific infectious arthritis. However, the attendant systemic manifestations associated with joint infections were absent.

Synovial effusions and tissues from joints included in this classification failed to yield organisms on bacteriologic studies. There existed, however, the possibility that idiopathic synovitis or arthritis was initiated by an infectious microorganism or combination of microorganisms. The infectious agent may not have been present in the synovial effusion or joint tissues at the time cultures were attempted or not in sufficient numbers for growth on artificial media (Coggeshall et al., 1941). The administration of antibiotics or sulfonamides may have exerted a growth inhibiting effect. Previous exposure to an unknown microorganism and hypersensitivity to that microorganism on subsequent exposure or exposures may have initiated an

inflammatory response by the joint and may explain in part the pathology encountered in affected joints which were apparently sterile (Neher, 1958).

Infectious Arthritis

In cattle, streptococcal and coliform polyarthritis are considered by Jubb and Kennedy (1963) to be primarily neonatal in origin, while infections due to Corynebacterium pyogenes and Salmonella spp. may occur at any age. Tertiary infectious arthritis (associated with a septicemia or metastasis from an area of infection in some other part of the body not adjacent to the joint cavity) accounted for the greater number (88.8%) of infected joints. All but one calf affected with tertiary infectious arthritis were affected with a polyarthritis.

Primary infectious arthritis (due to penetration of a foreign object into the joint cavity) and secondary infectious arthritis (extension of infection from an area of infection adjacent to the joint cavity) were encountered in each of two calves. All of the calves were 17 days of age or younger, the neonatal site of infection being the umbilicus. Streptococcus viridans was the most frequently isolated organism (10 joints of 3 calves) followed by Escherichia coli (5 joints of 1 calf). The only mixed infection was composed of C. pyogenes and S. fecalis in one joint. One joint in each of two older cattle, 8 months and 3 years of age, respectively, were infected with C. pyogenes.

With the exception of chronic infectious arthritis due to C. pyogenes, gross and microscopic pathologic lesions were nonspecific in nature. Pathologic variations were attributed to the stage of the particular infection concerned.

Polyarthritis Associated with Primary Systemic Infections

Calves in this group were found to have a polyarthritis secondary to systemic infections or infections localized in various body organs. Attempts to culture bacterial organisms from the joint effusions met with no success. No attempt was made to culture for Mycoplasma spp. or viruses. In spite of an inability to isolate bacterial organisms from synovial effusions and tissues, the inflammatory response in the affected joints was considered an integral part of the syndrome. Effusions into the joint cavities often appeared at an early stage and were considered part of the edema associated with systemic infection or an infection localized in one or more body organs (Collins, 1949). Several factors may have accounted for the inability to isolate bacteria from joint effusions or joint tissues from these calves. There exists the possibility that the owner may have administered antibiotics or sulfonamides prior to the death of the animal or euthanasia for necropsy purposes. The etiologic agent may not have been able to grow in the joint

fluid following its localization in the synovial membranes due to the bactericidal properties of the synovial fluid. One should not discount the fact that an allergic manifestation may have had etiologic significance as a result of hypersensitivity to the invading microorganism.

It is interesting to note that polyarthritis was encountered in association with enteritis due to E. coli, Proteus mirabilis, Paracolobactrum spp., organisms that are generally considered normal inhabitants of the bovine intestinal tract.

Grossly, the most characteristic lesions were those of hyperemia and edema of the synovial membranes. Subsynovial petechia and ecchymosis were not uncommonly observed in acute or subacute polyarthritis. The duration of the joint inflammation was rarely long enough to produce extensive damage to the joint tissues.

The most pronounced microscopic lesions were those of hyperemia, congestion, edema, and subintimal hemorrhage. Inflammatory cells were composed primarily of neutrophils, with a scattering of lymphocytes throughout the stratum synoviale. The stratum fibrosum in general was markedly thickened by fibrous tissue. The surfaces of the articular cartilages had undergone loss of their normally smooth outline, with occasional longitudinal splitting. In the most advanced cases, chondral pannus formation at the confluence of the synovial membrane and the articular cartilages was a consistent finding.

VI. SUMMARY AND CONCLUSIONS

Synovial fluid specimens from 117 joints of 82 cattle of various breeds, ages, and sexes affected with a wide variety of joint diseases were investigated. Where applicable, synovial fluid values were compared with their respective whole blood or serum values.

Pathologic effusions were classified on the basis of etiology, pathogenesis, anamnesis, clinical symptomatology, arthrographs, synovial fluid analyses, and bacteriologic studies. Hematologic studies were employed to ascertain the systemic effect, if any, exerted by the various types of joint disease.

Group I--Synovial Effusions that Resemble Normal Synovial Fluids: Synovial effusions in this group were transudative in nature. Effusions from cattle affected with degenerative joint disease were slightly in excess of normal volume, whereas effusions from cattle affected with tarsal hydrarthrosis were greatly in excess of normal volume; however, these effusions most closely paralleled normal synovial fluid with respect to their various constituents in contrast to effusions from cattle affected with acute and chronic traumatic arthritis. Synovial effusions from cattle affected with acute and chronic traumatic arthritis were

slightly in excess of normal volume and generally sanguineous to hemorrhagic in nature. Relative viscosity values for the entire group fell slightly below normal. Tests for quality of mucinous precipitate indicated a hyaluronic acid content with a relatively high degree of polymerization. Synovial fluid sugar levels closely paralleled their blood sugar levels in cattle affected with degenerative joint disease and tarsal hydrarthrosis, but exceeded their blood sugar levels for cattle affected with acute and chronic traumatic arthritis.

Synovial fluid alkaline phosphatase activity with the exception of cattle affected with tarsal hydrarthrosis, exceeded that of its serum counterpart. Lactic dehydrogenase activity, glutamic oxalacetic and glutamic pyruvic transaminase activity for synovial fluid, was found to be significantly less than the activity of their serum counterparts for cattle affected with degenerative joint disease and tarsal hydrarthrosis. Total synovial fluid leukocyte counts for all cattle in this group were slightly higher than reported normal values.

Group II--Intermediate Synovial Effusions: Synovial effusions from cattle affected with an idiopathic arthritis were predominantly exudative in nature. Attempts to culture microorganisms from effusions in this group met with no success. Total volume was in excess of normal, relative

viscosity was reduced, and tests for mucinous precipitate indicated a low degree of hyaluronic acid polymerization or a low ratio of hyaluronic acid to unit volume. Mean synovial fluid sugar levels were found to be 32.7% lower than their blood sugar levels. Synovial fluid lactic dehydrogenase activity, glutamic oxalacetic and glutamic pyruvic transaminase activity was higher than reported synovial fluid values for cattle. The exudative nature of the synovial effusions was confirmed by the high total leukocyte counts and the high absolute number of neutrophils.

Group III--Septic Synovial Effusions:--Synovial effusions from joints with infectious arthritis were almost entirely exudative in nature. Total volume was greatly in excess of normal, relative viscosity was reduced and tests for mucinous precipitate indicated a hyaluronic acid content of an extremely low degree of polymerization or almost complete absence of the hyaluronic acid complex. Synovial fluid sugar levels were found to be 48% lower than their blood sugar levels. Alkaline phosphatase activity for synovial fluid was in excess of its serum counterpart, but did not attain the level reported for normal cattle. Synovial effusions confirmed their exudative nature by their high total leukocyte counts, and high absolute number of neutrophils. Infectious arthritis was reflected systemically by a granulocytosis in the peripheral blood.

Gross pathologic and histopathologic studies were performed on 76 joints of 32 cattle. Joint specimens were obtained at necropsy or by punch-biopsy.

The most significant gross lesions in degenerative joint disease were confined to the articular cartilages. The most characteristic findings were a yellowing and thinning of the articular cartilages, with irregular depressions, flaking, pits, and linear grooves. Microscopically, there was a loss in the hyaline appearance of the cartilage, a reduced number of chondrocytes, and fibrillation of the matrix.

The principal gross pathologic lesions in chronic traumatic arthritis were confined to the synovial membrane and consisted primarily of subintimal hemorrhages. Microscopically, subintimal hemorrhage and edema were the most consistent findings.

The joints of cattle affected with an idiopathic synovitis or arthritis were found to resemble infectious arthritis both grossly and microscopically.

Streptococcus viridans was isolated most frequently from the joints of cattle affected with infectious arthritis. Gross and histopathologic lesions varied directly with the virulence of the microorganism. The most severe joint infections were associated with chronic infectious arthritis due to Corynebacterium pyogenes.

Attempts to culture microorganisms from the joints of cattle affected with a polyarthritis associated with primary systemic infections met with no success. Hematogenous spread of microorganisms from primary sites of infection to the joints or hypersensitivity to microorganisms were considered as possible causes of polyarthritis.

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