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A PATHOLOGIC-ANATOMICAL STUDY ON DISC DEGENERATION IN DOG

With special reference to the so-called
enchondrosis intervertebralis

BY

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To my Wife

PREFACE

The investigations on which this work is based have been made at the Department of Pathology at the Royal Veterinary College in Stockholm during the years 1949—1952.

Long before the works of *Schmorl*, in the late 1920's, had directed the attention towards the discs in the genesis of lumbago-sciatica in man, *Dexler* has described primary pathological changes in the discs in connection with a common type of back trouble in dog.

A study on disc degeneration in dog would of course be of great comparative interest, and after having conferred with my teacher and chief *Professor Sven Rubarth*, it was decided that this subject should be treated. I wish to express my deep gratitude to *Professor Rubarth* for valuable advice on the planning and carrying through of the investigation and for his kindness in reducing my routine work, thus facilitating the completion of my investigations.

With *Laborator S.-E. Olsson* an inspiring collaboration has taken place and I am most grateful to him for valuable discussions prolific of ideas and for all assistance given to me by him and his institution.

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Hans-Jörgen Hansen

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Chapter I

GENERAL INTRODUCTION

It has long been known that certain forms of disease in dog are caused by compressions of the spinal cord and/or the spinal nerve roots. Among the general possibilities of neurological damage of this kind especially one has been of interest for veterinary medical research. I refer to a disease that most frequently affects dogs of small, short- and bandy-legged breeds and which, ever since *Dexler*'s pioneering researches during the last years of the 19th century, has been known by the name of *enchondrosis intervertebralis* (e. i.).

This illness, the course of which is either acute and relapsing or chronical and lingering, shows clinically the richly varied disease picture, that is characteristic of a damage on spinal cord and/or nerve roots. In minor cases the disease may appear only as an hyperaesthesia of the skin, diffuse pains in the back and a general dorsal insufficiency, while in more serious cases it appears rather suddenly or is preceded by the above symptoms as a more or less total paraplegia. Even in grave cases the disease shows a tendency to spontaneous healing, though the risk of a relapse is considerable. The immediate cause of this damage to spinal cord and nerve roots is constituted by one or several cartilaginous formations in the ventral region of the extradural space. According to the name of the disease these formations show, more or less clearly, a direct connection with degenerative changes in the intervertebral discs.

Though the name e. i. gives in itself a morphologically clear definition and diagnosis no satisfactory explanation of the real morphological nature of the disease has been made. Nor has anybody been able to throw light upon its formal and causal genesis. This circumstance is easily explained by the fact that no comprehensive systematic research has been made on the pathological anatomy of the intervertebral discs. Thus, the knowledge that may be gathered from current literature in this respect, is founded on observations of single cases or of a certain number of relatively small series of serious cases, where most of the interest has centered on the neuropathological picture and the compression of the spinal cord in the first place, as being the immediate cause of the clinical symptoms, while less attention has been paid to changes in the discs. The disease is more often found in both original works and textbooks under headings like diseases of the central nervous system, compression myelitis, compression of the spinal cord, posterior paralysis, dachshund paralysis etc. I have found it desirable to try, to analyse, by means of a systematical, topographical and pathologic-anatomical study of the intervertebral discs in dog with special reference to the conditions connected with the so-called *enchondrosis intervertebralis* those processes which are the real characteristics of this disease. As has earlier been stated by *Tillmanns* (1939) and *Fankhauser* (1948) it has now been found that the formations which are bulging towards the vertebral canal are protrusions from the discs based on degenerative changes in the latter. Thus e. i. as a morphological diagnosis has become closer related to disc degeneration in man. For this reason I am going to follow common orthopedical custom and use the available nomenclature of human medicine where problems connected with this matter are of great current interest.[1]

This work being a pathologic-anatomical study of the intervertebral discs, a more thorough discussion of appertaining clinical-neurological and neuro-pathological problems will be made only by way of exception. Clinical studies on this disease with special reference to roentgen diagnosis and surgical treatment, partly based on the same material as has been used in this work, have recently been published by *Olsson* (1951).

The main conceptions on the pathology of disc degeneration in dog, which are presented in this work have previously been published in a survey by *Hansen* (1951).

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[1] *Definitions.*

Disc degeneration: Comprehensive denomination of all states showing degenerative changes in discs.

Disc protrusion: Protrusion of disc tissue into adjacent tissues and spaces. The word *prolapse* will be used as a synonym. Protrusion or prolapse refer to the very act of protruding as well as to the emerged substance.

Chapter II

HISTORICAL SURVEY

Disc degeneration and disc prolapse in dog

In this survey of the available literature the author intends in the first place to show the earlier conceptions on the nature of the formations which encroach upon the space in the vertebral canal and which form the clinically important manifestation of the disease. In the next place will follow a summary of the main ideas on the causal genesis of the degenerative changes in the discs.

Already before *Dexler* had been able to establish, in his big work "Beiträge zur Pathologie und pathologischen Anatomie der Kompressionsmyelitis des Hundes", a connection between certain types of compressions of the spinal cord and pathological processes in the intervertebral discs similar cases had been described in literature. In 1881, *Janson* relates a case of enchondroma in the vertebral canal of a young dachshund, killed because of a sudden paraplegia. It was located between the 4th and 5th lumbar vertebrae and the author states rather definitely that:

> "ein Zusammenhang des Tumors mit der Intervertebralscheibe kann nirgend festgestellt werden; letztere ist vielmehr vollkommen intakt".

This observation is interesting as it is the only report on a chondroma in dog localized to the epidural space only. If, however, the above case permits a suspicion of a connection between tumor and disc, this is still more probable in the case of paraplegia in a 3-year old pincher described by *Kitt and Stoss* (1883) as a "*circumscript pachymeningitis externa chronica*". In the thick deposits on the outside of the dura the authors observed cartilage among other things.

In 1893 *Dexler* describes three different types of *pachymeningitis chronica ossificans*, one of these types being characterized by isolated osseous islands. They were always localized to the intervertebral discs and firmly connected to the latter. Histologically they were formed by richly vascularized cartilage and bone. In his work of 1896 *Dexler* makes a difference between two types of chronical spinal cord compressions, *one caused by a primary disease in one or several interverte-*

bral joints and a secondary ossifying pachymeningitis and the other being the consequence of a disseminated, slowly progredient ossification process in the dura. *Dexler* describes eleven cases of the first type making a careful histological analysis of the pathology of the spinal cord compression. However, his comparatively cursory examination of the intervertebral discs brought him to the following conclusion:

"Die Affection ist eine durch spontan auftretenden degenerative Vorgänge am Knorpel und Knochen ausgezeichnete Gelenks-Erkrankung der Wirbelsäule, die mit hyperplastischen Wucherungsprocessen an den Zwischenwirbelbändern verbunden ist".

These ossifiable cartilaginous excrescenses, in their turn caused a reactive inflammation of the vertebral periosteum, the epidural space and the dura. Thus the primary rôle of the discs in these types of compression myelitis is emphasized already by *Dexler*. Degenerative changes in the inner parts of the discs have been a recurrent theme in all after-*Dexler* literature, which, although relatively sparse, has discussed these problems. However, differing opinions on the nature of the formations intruding on the space in the vertebral canal have been offered by several authors.

In 1910 *Jakob* observes, that paraplegia in dachshund is

— "eine Folge seiner ungünstigen Bauart". —

The back of the dachshund, being long compared to body height, was supposed to be liable to produce overtensions during the animal's movements, in the first place of the spinal nerves, but also of the ligamental system of the spinal column, including the discs. *Jakob* seems to have regarded the posterior paralysis or paraplegia common to the dachshund as a mainly neurogenic insult, though he has stated that in some cases a primary injury in the discs should be taken into account. Through repeated traumata this tissue might react by means of degenerative and inflammatory changes causing an increase of volume and often also an ossified protuberance into the vertebral canal. From a differential diagnostic viewpoint *Jakob* makes a difference between these injuries and e. i., which is, according to him, a chronic and incurable ailment not restricted to the dachshund breed.

In 1921 *Joest* gives a description of e. i. as a disease that appears in aged dogs, preferably dachshunds. *Joest* has not observed the above-mentioned conclusion of *Dexler*, and so he has cited the latter somewhat incompletely when stating that *Dexler* has conceived the formations in the vertebral canal as inflammatory processes, emanating from the vertebral periosteum and later on becoming the site of metaplastic formation of cartilage and of calcification. In this connection *Joest* makes the following interesting reflexion in a foot-note:

"Bei der Untersuchung mehrerer Fälle auf medianen Durchschnitten durch die Wirbelsäule und bei Vergleich normaler Wirbelsäulen von Dachshunden (ebenfalls auf medianen Durchschnitten) gewann ich den Eindruck, als ob die Veränderung von Nucleus pulposus (Dem Chordarest) der Zwischenwirbelscheiben ausgeht. Nähere Untersuchungen müssen lehren ob dies zutrifft."

Wiedemann (1922) very carefully describes a case of e. i. and shows histologically that regressive and progressive processes are going on at the same time in the discs concerned and that the formations in the vertebral canal are caused by this cartilage growth. He denominates the extradural neoformations as "ekchondromas".

During the following decades, when the works of *Schmorl* (1926—1927, 1928, 1929) in human medicine resulted in a gradually increasing attention to the connection between the intervertebral discs and sciatica and opened an era of intensive research and new literature in this field, veterinary medical literature is rather deficient in works of this kind.

Brook (1936) describes a case of hypertrophia of the lumbo-sacral disc with a transversal bulge towards the vertebral canal in a 4-year old experimental mongrel dog.

Not until 1937, however, this subject was discussed again in a comprehensive original work, this time by *Pommer*. *Pommer*'s opinion is that it is a question of primary degenerative changes in the discs, resulting in calcification and protrusion towards the vertebral canal. In another chapter of his work he regards these protrusions as cartilaginous tumors or proliferations emanating from the intervertebral discs and for that reason he suggests that they be denominated "*ekchondrosis*" instead of "*enchondrosis*". *Pommer*'s work is a radiological contribution to the discussion on this subject and it contains no other observations by the author of patho-anatomical nature.

In 1939 *Kirk* describes a case of *calcinosis intervertebralis* in a 3-year old pekinese, located to two discs in its neck. He considers this a part phenomenon of a process described by *Hutyra-Marek* (1922) as *enostosis intervertebralis*. This latter should in fact be identical with the *spondylosis deformans*.

After a very careful study of 13 cases of e. i. *Tillmanns* (1939) was able to sum up his observations as follows. He makes a distinction between two different types of stenosis in the vertebral canal, emanating from the discs: firstly, those in dachshund and similar dogs, appearing as solitary and unilateral phenomenons, secondly, those appearing as multiple and symmetrical phenomenons in aged dogs of different breeds on both sides of the lig. longitudinale dorsale. He proceeds to state:

"Beide Formen der Wirbelkanalstenosen gehen pathogenetisch primär auf Veränderungen an den Zwischenwirbelscheiben zurück, welche in Knorpeliger

Umwandlung des Nucleus pulposus, Auffaserung des Annulus fibrosus und Vorquellen des Chondroiden Zwischenwirbelscheibenzentrums in dorsaler Richtung bestehen."

Thus, *Tillmanns* was the first one to show, that the cartilaginous formations appearing in the ventral part of the epidural space during e. i. might be prolapsed disc tissue.

In a short exposé on nervous ailments in lower animals *Schlotthauer* (1940) states that he has observed a case of disc prolapse in dog resulting in progressive paralysis of the hind legs and urinary and anal sphincters.

Schnelle (1945) states that calcifications of the discs seem to be rather uncommon in dog. He then gives two examples of *calcinosis intervertebralis*, in one case a spaniel with back pains, in the other a dachshund with relapsing paraplegia.

In 1946 *Riser* published a work on the rôle of the intervertebral discs in posterior paralysis. In his survey of the literature he only accounts for those few american authors who have treated this subject (*Schlotthauer*, *Schnelle*), and the europeans *Janson*, *Jakob* and *Brook*. *Riser* then describes his own experience of disc protrusions in dog, all of which corresponds quite well with what has earlier been known as *e. i.* The morphological base of the disease is, according to *Riser*, a rupture in the annulus fibrosus combined with a prolapse of disc tissue. The rupture may be partial with a bulge of remaining lamellae, or it may be total.

Fankhauser (1948) has brought the idea of a mere prolapse one step further. He uses the following words:

"Auf histologischen Schnitten erkennt man, wie das fibröse Gewebe an der Peripherie des Prolapses mit dem Annulus fibrosus, die weichen Massen in seinem Innern jedoch mit dem Nucleus pulposus zusammenhängen."

Like *Tillmanns* also *Fankhauser* points out that there are two types of disc protrusions in dog that differ as well in their clinical as well as in their pathologic-anatomical pictures. Thus he states that he has the impression that the big protrusions appearing in dachshunds and similar dogs are at least partially the manifestations of a productive process, while those appearing in bigger dogs should be more of a purely mechanical process accompanied by protrusions (*Frauchiger and Fankhauser* 1949). *Pommer* (1933) and *Fankhauser* (1948) have also regarded these disc protrusions as part phenomenons of the *spondylosis deformans*. *Olsson* (1951) presents some views on the dynamic background of the disc protrusions. *Olsson's* work gives a contribution to the knowledge of the practically important part of the formal genesis of the disease that concerns the further development of the already existing protrusions.

In his work on differential diagnosis of paraplegia in dog *Boddie* (1949) ends with the following assertion:

> "I have never seen either ossification of the intervertebral discs or prolapse of the disc. — — — Prolapse of the disc in a manner comparable to that seen in man is anatomically impossible in the dog."

As a summary of this revue of literature one may set down that the disease usually called "e. i." has, in accordance to its name been rather uniformly conceived as an ailment primarily localized to the discs. After that suggestions of various progressive and inflammatory neoformations have been offered, the neoformations which encroach on the space in the vertebral canal have in later times been described as prolapsed disc tissue.

Concerning the causal genesis of these disc degenerations and protrusions only sparse observations are to be found in literature and practically no one based on a systematic investigation. *Dexler* (1896) was unable to find an obvious cause for the disease, because his material did not show any dispositions as to breed, age or sex. *Dexler* only could observe that the disease was of a non-tubercular nature. *Jakob* (1910), as has already been mentioned, considered that paraplegia in dachshund was the consequence of its unfavourable bodily structure with its pronounced disproportions between height of body and length of back. *Jakob* stated that this mechanical factor caused the ailment, which was more often of a neurogenic than a discogenic nature. Later literature has always referred to this mechanical factor together with various traumata. Thus *Miller* (1948), e. g., is of the opinion that disc prolapse in dog should mainly be confined to male dogs and ensue from copulation. *Pommer* (1937) suggests the possibility that acute and chronic infectious diseases and also endocrine factors may be of importance to the genesis of these injuries and *Fankhauser* (1948 a) puts the question if the low disease resistance of the intervertebral discs may not be referred to the same fundamental causes as the short- and bandyleggedness of the concerned breeds — i. e. dwarfishness, chondrodystrophia. *Löfstedt* (1941) considers, that the good effect of vitamin B therapy is an observandum in searching the etiology of this disease.

This short recapitulation of the conception of the causal genesis of disc degeneration may be somewhat misleading insofar as it has occasionally included views on other types of back pains and paraplegia. Clinical statistics on the causes of back diseases in dog are seldom to be found in literature and thus we may only reach an approximate idea of the part played by diseases in the intervertebral discs. *Pommer* (1933) found *spondylosis deformans* in 36 % of 736 dogs that had been X-rayed for back injuries. In 1937 the same author made roentgenologic observations on 342 cases of disc degeneration in 1162 dogs and cats with posterior paresis, i. e. 29.5 %. *Olsson* (1951) has been able to show by his myelographical studies that many of those cases which have earlier been regarded as rheumatoid myalgias or neuralgias have disc protrusions. *McGrath* (1951) accounts for 24 cases of "Intervertebral Disc Syndrome" among 79 post mortem cases showing the clinical picture of spinal paralysis. From obvious reasons I am not able to present a reliable statistic survey on the causes of clinically manifest cases of back ailments. However, this work will show that morphological expressions for a disc degeneration are very often to be found in dogs.

Disc degeneration and disc prolapse in other animals

In the textbook of *Hutyra-Marek* (1945) it is mentioned that *Marek* has observed cases of *enchondrosis intervertebralis* in two young pigs and one colt! In 1951, *Böhler, Gjestvang and Slagsvold* report cases of intraspinal disc protrusions in cattle, suffering from a certain kind of *impotentia coeundi.* In some of the cases these protrusions were the expressions of a spondylosis. Ruptures of the annulus fibrosus in the lumbo-sacral disc of a characteristic pattern have been observed in cattle whose anamnesis has contained no data on back trouble (own unpublished investigations).

Disc degeneration and disc prolapse in man

The clinical term, sciatica, wellknown in human beings and first described by the neapolitan *Cotugno* (1764), has since then been interpreted in different ways. Myogenic and neurogenic factors together with various intraabdominal diseases have alternatingly been hold responsible for the "sciatic syndrome", but during later years the rôle of the discs in this disease has come more and more into the foreground. In 1937 *Barr* recommends that disc injury be suspected in all cases of lumbago-sciatica, in 1942 *Lindblom* wanted to put the sign of equality between sciatica and disc prolapse, and in 1951 the same author considered that also in lumbago is the predominant part played by disc degeneration.

Lumbago-sciatica is a clinical term, and I am not going to discuss it in detail. But it is worth mentioning that important anatomical differences between man and dog must, of course, result in differences in the clinical manifestations of the disc degeneration. The pathologic-anatomical base is, however, of a similar nature in both cases. The dissimilarity between the clinical pictures are due to the fact that the discs most usually affected in man, i. e. those of the lower lumbar region and the lumbo-sacral disc are unable to injure the spinal cord, which ends at the first or second lumbar vertebra. Instead, nerve root compression becomes the clinically most important manifestation of the disease in man.

Before the significance of disc protrusion in lumbago-sciatica was recognized, the conception of these processes in the discs developed much along the same lines as that of veterinary medicine which has been described in the above.

Since long the cartilaginous formations which have often been observed adhering to the discs in the extradural space have been regarded as genuine tumours. In a comparison of 330 spinal tumours *Steinke* (1918) found 55 extradural ones. Among those were fibromas and enchondromas. Ventral extradural chondromas have ever since been the subject of a great number of casuistic observations in literature. In this connection I only want to mention two works by *Elsberg* (1928 and 1931).

In the late 1920s *Schmorl* drew attention to the occurrence and frequency of pathological changes in the discs of human beings. While he was working at a very comprehensive post mortem material he found that the displacement of the nucleus pulposus into the spongiosa of the vertebral body was a common phenomenon (1926—27). At first *Schmorl* regarded these formations as chordomas. Already in 1858 *Luschka* had described in his big monography two cases of dorsal disc protrusion, which he also considered as chordomas and thus as being identical to the chordoid tumours on the *Clivus Blumenbachii* that had been described by himself and by *Virchow* (1857). However, *Virchow* (1863) disputed this thought on account of the fact that these cartilaginous knots lacked so-called physaliforme cells. Instead he suggested the denomination "ekchondroma". *Schmorl* (1928, 1929) and *Andrae* (1929) rediscovered these cartilaginous formations on the dorsal side of the discs and were able to trace them to the *nucleus pulposus* via defects of the *annulus fibrosus*. During the immediately following years this discovery led to a successive revisal of the conception on the "ventral extradural chondromas". *Alajouanine and Petit-Dutaillis* (1930) wanted to identify them with "Schmorls Knorpelknötchen". *Elsberg* (1931) did prove most clearly the histological similarity between these "chondromas" and normal discs. However, *Elsberg* did not altogether want to abandon the term "chondroma", but considered "*ekchondrosis*" a more adequate denomination. *Mixter and Barr* (1934) were at last able to establish definitely that the "ventral extradural chondromas" were identical to "*Schmorls* Knorpelknötchen" or, in other words, that they consisted of protruded disc tissue. Furthermore they showed, that nerve root compression caused by pathological changes in the discs was a common cause of sciatica. By means of these investigations the observations of *Luschka* and *Schmorl*, the extradural chondromas and the term of sciatica had been synthesized into a tangible unit. Both *Luschka* and *Schmorl* had, however, intimated, that these morbid processes might be of clinical importance. After *Mixter and Barr* the chondromas have practically vanished from literature and the rôle played by disc protrusion has been considered more and more important. Also, since then pathologic-anatomical studies on the intervertebral discs with reference to these problems have been published (*Keyes and Compere* 1932, *Deucher and Love* 1939, *Saunders and Inman* 1940, *Coventry, Ghormley and Kernohan* 1945, *Eckert and Decker* 1947, *Friberg and Hirsch* 1949, *Lindblom and Hultquist* 1950 and others), but I will discuss them later on in this work in connection with my own investigation.

It might perhaps be appropriate to conclude this historical survey by paying a compliment to the pioneering work of *Dexler*. In a recently published article *Frauchiger* (1951) has written a memorial of professor *Hermann Dexler* and concerning the problem of interest to the present work he states as follows:

"Als erster und mit klarer Dokumentation hat *Dexler* schon in den beginnenden neunziger Jahren des vergangenen Jahrhunderts über die Kompressionserscheinungen des Rückenmarkes durch Bandscheibenwucherungen beim Hund geschrieben und dabei die sogenannte Dackellähmung als *Enchondrosis intervertebralis* gedeutet. Wenn in den letzten Jahren in den Human-Neurologie besonders in der Neurochirurgie den Zwischenwirbelscheiben in steigendem Masse Beachtung geschenkt wird da Diskushernien oder Bandscheibenprolapse zu Schweren "Ischias-Neuralgien" führen können, so darf hier mit allem Nachdruck darauf hingewiesen werden, dass dank den Untersuchungen von *Dexler* in der Bandscheibenpathologie der Veterinär-Neurologie der humanen um Jahre vorausgegangen ist."

Chapter III

THE ANATOMY AND PHYSIOLOGY OF THE VERTEBRAL COLUMN IN DOG WITH SPECIAL REFERENCE TO THE INTERVERTEBRAL DISCS

Introduction

"When man assumed the upright posture he not only set himself apart from the animal kingdom, but he also set the stage for a series of disorders of the low back, which have plagued him since."

I have chosen to cite this statement by *Splithoff* (1946), because it is a conclusion of interest to comparative medicine. It is now known that these disorders of the low back are mostly lesions in the intervertebral discs, and thus the above statement might make the erect posture a priori responsible for the predisposition to disc injuries in man. However, this work will prove, that there is at least one representative of the animal kingdom, viz. the dog, in which intervertebral disc lesions are often found. It therefore can be considered advisable to initiate the reader into the anatomy and physiology of the spinal column in dog. My statements are based on the available textbooks on domestic animal anatomy, the relatively sparse special literature and original works on this subject and on my own observations.

The spinal column as a whole

The dog has 7 cervical, 13 thoracic, 7 lumbar, 3 sacral and some 20 coccygeal vertebrae. The number of vertebrae between head and *os sacrum* is consequently 27 and does not vary according to breed. In 7 of 242 examined backs I have found only 26 vertebrae, owing to lack of a thoracic vertebra (5 cases) or a lumbar vertebra (2 cases). The total length of the vertebral column of course shows great variations according to breed. If the length of the trunk is put in relation to the height at withers thus giving us a value of the proportions of the animal, we will also be able to observe a great deal of breed variations. I will return to this question in the next chapter.

The vertebral arches are bigger compared to the bodies of the vertebrae than is the case in man and the vertebral canal is of considerable width. The latter is, according to investigations by *Hart* (1925), subjected to breed variations in as much as it is comparatively wider in small dogs than in bigger ones. The same goes for puppies compared to adult dogs.

The so-called *diaphragmatic vertebra*, i. e. the vertebra where the change from horizontal or tangential to vertical or radial surfaces of the joints of the *procc. articulares* does take place is the 10th lumbar vertebra in dog, while the 11th one is the so-called *anticlinic vertebra*, which marks the transition from backward sloping to forward sloping *procc. spinosi* (*Slijper*, 1947). The transition from tangentially to radially positioned joint surfaces on the *procc. articulares* defines the point on the vertebral column, caudally from which a rotation is no longer possible. From the 9th thoracic vertebra and backward an independent process issues caudally from *proc. transversus* and gradually it reaches its full development in the lumbar vertebrae, where it is called *proc. accessorius*. Between the latter and *proc. articularis caud.* is formed a narrow space, in which the *proc. articularis cran.* of the next vertebra is fitted. This results in a very efficient wedge system that contributes to render torsional movements impossible. Also, caudally from the 10th thoracic vertebra the *mm. rotatores* specially adapted to such movements are lacking.

The lateral projection of the vertebral column shows a rather obvious invariability, though certain minor characteristics of breed are to be found. *Reuter* (1933) examined the "Eigenform" of the vertebral column in dog. She made use of a definition invented by *H. Virchow*, by which he meant the shape that the vertebral column assumes when relieved of head, ribs and muscles. The study of *Reuter* showed that the spine of the dog has three characteristic convexities. The two first cervical vertebrae are forming a dorsal convexity together with the head, the last caudal ones and the first thoracic vertebrae give a very pronounced ventral convexity and the remaining thoracic and lumbar vertebrae are forming a shallow dorsal convexity. This latter thoracolumbar kyphosis is more pronounced in dachshund, as is the case in cat (*Auer* 1914), with sloping lumbar part and a hunch formation just on the transition between the thoracic and lumbar region. Concerning man, *Bakke* (1931) has studied the "Eigenform" of the vertebral column. He, however, used this term to design the position of equilibrium which the vertebral column is always trying to regain. In man he thus found an arch convexing forwards in the cervical and lumbar region and an arch convexing backwards in the thoracic region. The reason for these bends of the vertebral column is, according to *Bakke*, mainly to be found in the anterior and posterior variations in the height of the disc.

The vertebral column of the vertebrates have of old been regarded as a truss (*Zschokke*, 1892) with its points of support at the two pairs of extremities.

According to this conception of the vertebral column as a truss the stress when the load is applied from above would have to be greater at the points of support than in the middle. The problem of which point of the vertebral column will be subjected to the greatest mechanical stress must of course be approached from several directions, and the shape of the vertebral column and its general mechanism of movements must be taken into account.

Slijper repudiates the theory of *Zschokke* on the mechanical nature of the vertebral column and prefers to compare the spine and the mechanism that serves to bend or straighten it to a bow and string. He also brings attention to the anticlinical phenomenon that is well developed in dog, cat and pig, not very developed in horse and completely lacking in cattle. In them the *procc. spinosi* are sloping backwards all along the spinal column. This fact is of importance to the mechanics of the spine.

The spinal column of animals with pronounced anticlinia is flexible and the movement is mainly localized to the area of or around the diaphragmatic and anticlinical vertebrae. The muscle of importance in this connection is the *m. longissimus dorsi*. This muscle contains a bundle of long root tendons on the *procc. spinosi* caudally to the anticlinical vertebra and the course of these tendons is cranial and slightly ventral towards the transverse processes of the dorsal vertebrae and the ribs. The abovementioned processes are sloping forwards, thus forming an angle between themselves and the root tendons that is optimal to the effectiveness of the *m. longissimus dorsi*. In animals with slightly developed anticlinia or none at all the spinal column is on the contrary only slightly flexible in the region immediately cranially to the diaphragmatic vertebra. From this limited faculty of motion, however, the animals benefit especially when grazing. For that reason the animals, when galoping, do not bring their hind legs forwards by means of bending their spine. Instead they use their lumbo-sacral joint. This trait is very pronounced in cattle, and for this reason a backward sloping of the spinous processes in these animals is well adapted to its purpose with regard to the caudo-ventral course of *m. multifidus dorsi*, which is attached to these processi. *Reuter* gives the following succession of the faculties of movement of the spinal column in dog, as it seems without taking into consideration the nature of the movements. Most

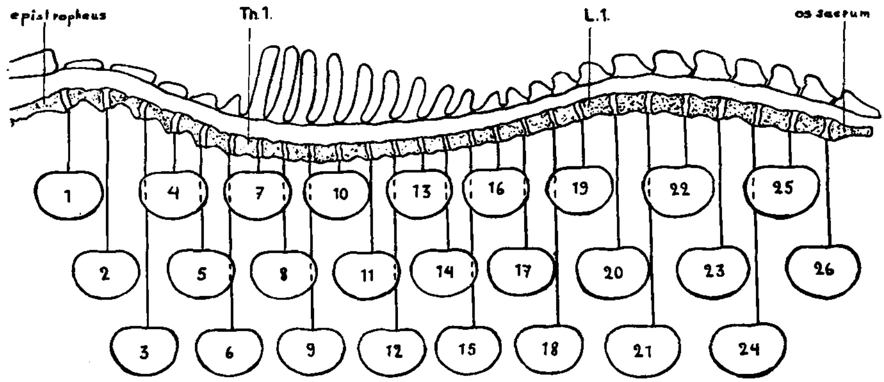

Fig. 1. The type of record used in this work. The picture also shows the numbering of the discs.

mobile is the tail, then successively the cervical region from the atlas onwards, the thoracic region, the atlanto-occipital joint, the lumbar region and last the immobile *os sacrum*. This scheme shows the variation of mobility in anatomically demarcated parts of the spinal column and thus it hides the most important centre of mobility at and around the diaphragmatic and anticlinic vertebra, which has been pointed out by *Slijper* and where the "bridge" between the fore and hind legs is, according to this opinion most likely to be subjected to the greatest mechanical stress.

The intervertebral discs

From the second cervical vertebra to the lumbo-sacral joint there are 26 intervertebral discs. In this work the discs will be numbered from 1 to 26 according to *Fig. 1.* Thus number 1 is the disc between epistrophaeus and the third cervical vertebra, no. 19 is the thoraco-lumbar and no. 26 the lumbo-sacral disc.

Bradford and Spurling (1947) mention that the total length of the discs in man is 25 % of the length of the vertebral column. Similar dates on dog have never been given, and as such dates might be of interest from a comparative viewpoint the author has measured the length of the vertebral columns and the discs in a number of dogs of different breeds. The term length of disc will be used in the following to designate the cranio-caudal measure of the disc (i. e. disc height in man). The measurements have been made in the vertebral canal close to *lig. longitudinale int.* by means of a ringhead bow divider and the measures have been set off on a transverse scale which is accurate to tenths of millimetres.

The material used has consisted of 18 dogs of different breeds: dachshund, poodle, "Dachsbrache", swedish hound, spitz, fox terrier and mongrel. The length of the discs compared to the total length of the spine averaged 17.4 per cent in this material (range=16.0—19.5). It is of course impossible to decide if this figure differs significantly from that given by *Bradford and Spurling* for man, 25 %. But it might be of interest to compare this figure in dog to a corresponding one in an animal which seems indifferent to diseases in the discs. For this reason cat has been selected as being closely allied to dog. This material has consisted of 5 cats and the method of measuring has been the same. It was found that the discs in these animals accounted for 11.8 % of the length of the vertebral column (range=10.8—12.9).

TABLE 1.

Analysis of variance of the relative length of the discs in dogs and cats.

Source of variation	Sum of squares	Degrees of freedom	Mean square
Between dogs—cats	122.22	1	122.22
Within dogs—cats	21.78	21	1.04
Total	144.00	22	

Ratio of mean squares: $\frac{122.22}{1.04} = 117.52^{***}$

This table shows a statistically highly significant difference between dog and cat, concerning the relative length of the discs.

Hitherto it has not been shown that disc diseases should be important in herbivorous animals. For this reason a comparison between dog and some herbivorous animals might be of interest. The corresponding statistical material on horse has been presented by *Wenger* (1915). *Table 2* is based on this material, consisting of 4 horses, which showed an average relative length of the discs of 11.1 per cent (range=10.0—12.1).

Table 2 shows a statistically highly significant difference between the relative length of discs in dog and horse.

TABLE 2.

Analysis of variance of the relative length of the discs in dogs and horses.

Source of variation	Sum of squares	Degrees of freedom	Mean square
Between dogs—horses	130.47	1	130.47
Within dogs—horses	21.89	20	1.09
Total	152.36	21	

Ratio of mean squares: $\frac{130.47}{1.09} = 119.70^{***}$

The above figures might, it seems, point to the possibility of a positive correlation between disc length and disposition for disc injuries. This is also indicated by *Bakke*'s measurings of the disc height in the lumbar region in man, in which the two lowest discs, which are those most often subjected to disc degeneration, were also those of the greatest height. In a following chapter we will find that disc degeneration in dog shows pronounced variations according to breed. For this reason it might have been of interest to see if there is any difference between the relative disc lengths in different breeds. A trial has been made to solve this problem, the present small material being used for this purpose. An analysis of variance did not, however, give any proper results in this respect.

The length of the discs varies in the different parts of the vertebral column in the following manner. If an exception is made for the lumbo-sacral disc, the length is greatest in the cervical region and smallest in the part of the thoracic region that corresponds to the 9 sternal ribs, after which the discs grow longer successively towards the lumbar region, where they show a rather pronounced constancy. The length (in man=height) of the discs is of course an important factor to the possibilities of movement of the vertebral column. According to *Fick* (1911) the mobility is directly proportional to the square of the disc height and inversely proportional to the square of the diameter of the disc. The same formula has been used in a modified form by *Schrader* in investigations on the possibilities of movement on the vertebral column.

The discs are very closely connected to the vertebral bodies, and the mobility of this connection is not only determined by the size and general nature of the discs themselves but also by the other joints of the vertebrae and by surrounding osseous parts, ligaments and muscles. *Coventry, Ghormley and Kernohan* (1945) contest the opinion forwarded by several earlier authors (*Luschka* 1858, *Smith* 1931, etc.) that there exists a central joint cavity. Neither has anything been found during the present investigations on the discs in dog that points at the existence of a synovial cavity in the intervertebral space.

The discs are surrounded and supported by the two *ligg. longitudinalia* and concerning the 9 first segments of the thoracic region, by all the ligaments that keep the ribs suspended. Of special interest in this connection is the *lig. conjugale costarum*, which joints the *capitula costae* of the two sides and is shaped as a very broad and strong cartilaginous band (Fig. 13). This ligament can to a certain extent be regarded as a substitute to the outer dorsal layers of annulus fibrosus and it forms a roof over the disc under *lig. longitudinale internum*.

It is only developed at the 9 sternal ribs with the exception of the first pair of ribs and provides as will later on be observed the only reasonable explanation to the fact that exactly this part of the vertebral canal does never show any disc protrusions. In man the ligament corresponds to *lig. capituli costae interarticulare*, which fastens itself dorsolaterally on the disc and does not join the corresponding ligament on the other side.

Each disc consists of two parts: the *annulus fibrosus* (a. f.) and the *nucleus pulposus* (n. p.). In accordance with *Prader* (1947) the present author has found it most correct to count only these two components as belonging to the disc proper. In many works also the cartilage plate (c. p.) is added to the others.

N. p., oval-shaped and excentrically placed on the boundary between the middle and dorsal thirds of the disc, is a highly specialized structure, originating from the *chorda dorsalis*.[1] When the animal is born n. p. is a gelatinous mass of tissue, which is under a considerable pressure and is demarcated from the bodies of vertebrae by c. p. and enclosed by a. f. Its structure is subject to changes as the animal grows older and a more detailed account of this fact will be given in chapter V and VI.

C. p. consists of hyaline cartilage, fitted between n. p. and the epiphysis of the body of the vertebra. This epiphysis has a shallow impression corresponding to n. p. and which is perforated by innumerable very small holes, hardly discernible through a magnifying glass. In the centre of this impression especially younger animals show a more or less obvious rather small pit which is a mark left by the breaking through of the chord. The epiphysis of the vertebral body in dog thus forms an osseous tablet between diaphysis and disc with unbroken continuity and only a shallow impression towards n. p. In man the whole of this central component is missing, the epiphysis in consequence being a ring — the bony epiphyseal ring.

In an experimental study in animals on disc injuries and spondylosis *Lob* (1933, 1934) has observed this difference between man and quadrupeds. In this connection *Lob* states that what is c. p. in man is the epiphyseal line in animals. This statement might easily be misinterpreted to mean that animals do not possess a c. p. and *Lob* does not give any explanation on this point. For this reason it is of importance to mention, that in spite of the differences in the epiphyseal development one is able to find a c. p. of similar localization in animals. This

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[1] Embryological investigations on the discs in dog are according to current literature lacking.

fact is of course in complete analogy with the development of the epiphyses of the long bones, where the articular cartilage is known to be the only remaining part of the epiphyseal cartilage.

A. f. finally is the biggest and strongest structure of the disc. It is built from lamellae, of which the inner ones derive from c. p. and the outer ones are a direct continuation of Sharpey's fibres in the epiphyses of the bodies of the vertebrae. The lamellae pass from vertebra to vertebra, crossing each other at angles of 100—120° seen from the cranial or caudal sides. A. f. is approximately twice as broad on the ventral as on the dorsal side of n. p. *Schrader* (1930) has mentioned that the ratio between the dorsal and ventral breadths of a. f. is different in cervical, thoracic and lumbar regions. For dog he gives the figures 2.3, 2.8 and 2.0. The number of lamellae in the two sections is according to a present very approximate estimate 20—30 and 10—20 respectively. *Joplin* (1935) mentions that the number of lamellae in the lumbar discs of man is 10—12.

The nutrition of the disc is accomplished by means of diffusion currents from the vessels in the bone marrow of the epiphysis of the body of the vertebra. These vessels are in direct contact with c. p. at the abovementioned holes in the end of the epiphysis. The existence of vascular canals in the discs of young individuals as has been observed in man (*Uebermuth* 1929, *Böhmig* 1930, *Smith* 1931, *Coventry, Ghormley and Kernohan* 1945) has also been verified in dog during the present investigation. *Paulsson, Sylvén, Hirsch and Snellman* (1951) have studied the diffusion rate of various substances in bovine n. p. N. p. contains, according to these authors, interfibrillary pores, the average size of which should be about 15 Å.

The innervation of the disc. Luschka (1858) was the first man to demonstrate a nerve branch which ascends from the spinal nerves distally to the ganglion and which joins a sympathetic branch passing through *for. intervertebrale* recurrently. He called it the *sino-vertebral* nerve. *Hovelague* (1925), *Jung and Brunschwig* (1932), *Roofe* (1940) and *Viberg* (1949) have studied these circumstances. Except *Roofe*, who found nerve fibres in the outer parts of a. f., none of them has been able to find nervous elements localized to other places than the ligamental system surrounding the disc. Present investigations show that in dog there is a recurrent sino-vertebral nerve which innervates the epidural space. In the proper disc tissue no nervous elements have been found by means of the Palmgren method.

The physiology of the disc. The disc is the jointed connection between the bodies of vertebrae and is to resist all the stresses resulting from movements in such a connection. The semi-fluid n. p. that is kept in its place by a. f. and c. p. is a peculiarly active or dynamic portion of the disc, by reason of its turgescence, but it is a. f. that is the main determinator of the size and shape of the disc and which is also the seat of most of its strength and tenacity (*Coventry, Ghormley and Kernohan*). The water content in the nucleus and the resistance of the surrounding structures are determinating for the pressure within the disc and it may be taken for granted that there is an optimal degree of the size of these two factors. However, as we will see later on the different parts of the disc are subject to continuous changes as the animal grows older. These changes are likely to result in a deterioration of the functional possibilities of this organ. Among other things it is known, from the works of *Püschel* (1930) and *Keyes and Compere* (1932) that the proportion of water in n. p. of new-born individuals is about 88 % and that in old age it may reach a value as low as 69—70 %. Parallel with this successive dehydration a number of structural changes are taking place in the disc. Those changes will be discussed in chapter V and VI.

According to its design the disc will thus function as a shock absorber as well as a distributor of pressure. When a cranio-caudal compression takes place, the shock is absorbed by displacement of the nucleus in all directions as being an incompressible fluid and by dilation of a. f. All movements which cause compression of only a part of the disc will nevertheless result in an even pressure on the two ends of the bodies of vertebrae, because the pressure in a medium that contains a liquid will be uniform.

During the movements of the disc a. f. serves as an elastic membrane subjected both to pressure and tension. *Barr* (1937) was able to show that this elasticity must greatly be due to the turgescence of the nucleus. He found that it was possible to dilate a. f. by means of compressing the intervertebral space in a vise and that the disc regain its normal shape when the pressure was removed. He did this several times and always got the same result. If, however, he perforated a. f. when the disc was under pressure and nucleus was brought to disappear in this way, the disc was later on unable to resume its normal shape.

As a conclusion to this short survey of the anatomy and physiology of the discs it may be laid down how closely their different portions are attached to each other, structurally as well as functionally. This fact is confirmed in the studying of their embryology and histology, which will be discussed later on, and it should be regarded as a norm for the estimate of the pathology of the organ.

Chapter IV

STATISTICAL STUDY OF THE RELATIVE FREQUENCY OF DISC DEGENERATION IN DIFFERENT BREEDS, SEXES AND AGES

Introduction

The variety of disc degeneration in dog that has of old been called *enchondrosis intervertebralis* is conspicuous for an obvious predisposition of certain breeds. For this reason one might expect that a statistical and morphological study of these circumstances should result in valuable information on parts of the causal genesis. This has been done by the author as first part of the present investigations. The questions to which an answer has been sought are as follows:

1. Are there any statistically secured dispositive disc degeneration factors?
2. What is the nature of the patho-anatomical picture of these disc degenerations?
3. Is it possible to synthesize any dispositive factors that may possibly be found and the obtained morphological picture into a hypothesis on the causal and formal genesis of disc degeneration?

Literature

Dexler did not find any decided disposition of breed, sex or age, but *Jacob* stated that hardly any disease did appear as often in a certain breed as peripherical paraplegia in dachshund. He did not, however, identify this disease with e. i., which on the contrary he did not consider to be typical to the dachshund breed to the same high degree as the peripherical paraplegia. *Joest* did only observe the disease in brown male dachshund. Among 418 cases of disc degeneration *Pommer* (1937) found that more than half the amount consisted of dachshunds, and then the succession was: french bulldog, pekinese, japanese chin, fox terrier, spaniel, maltese and schnauzer. Scottish terriers and sealyham terriers were very scarce in this material. *Pommer* also found calcinosis and ekchondrosis often in the age of 3—8 years and more often in male dogs than i female ones. *Riser* writes that disc protrusion may be found in every breed with the following order between the most disposed breeds: pekinese, dachshund and cocker spaniel, that male dogs are more often affected than female ones and that the animals seldom become afflicted by the disease before they are two years of age but the disease is most frequent in the age-group 4—8 years. Approximately the same result is presented by *Mc Grath* (1951). Both *Tillmanns* and *Fankhauser* made a distinction between two types of disc prolapse, one being the classical e. i., which *Fankhauser* considered as a nearly exclusive feature in dachshund, pekinese and other small short- and bandy-legged breeds, with no sex disposition and preferably seen in middle-aged and older dogs. The other type was observed in comparatively old dogs of other breeds. *Fankhauser* in this connection especially holds forth the Alsatian dog. These disc protrusions are regarded by *Fankhauser*, as by *Pommer* (1933), as part phenomenons in spondylosis and *Pommer* was able to find that the spondylosis did not show any disposition as far as breed was concerned but above all afflicted working dogs and brisk dogs. He states further:

"Unter 290 Aufnahmen von Dacheln und *Dachsbrachen* bei welchen klinische Erscheinungen, die für eine Erkrankung der Wirbelsäule sprechen bekanntlich sehr häufig sind, zeigten nur 16 und 8 (3.8 %) spondylitische Veränderungen. Bei diesen Tieren ist das Leiden meist anderer Natur (Kompressionsmyelitis infolge Enchondrosis intervertebralis)".

The word "Dachsbrachen" has been printed in italics as being of special interest in this connection. It is namely the only observation found in literature submitting that this dog, closely related to the dachshund as it is, should be especially disposed towards e. i.

Material and methods

As will be found later on it is practically impossible to give a certain and detached definition of disc degeneration. In this study dorsal disc protrusions will serve as indicator of disc degeneration.

In order to reach an estimate of the relative frequency of cases of dorsal disc prolapses in both sexes and in different breeds, a material consisting of 100 cases has been selected among dogs examined post mortem during the years 1922—1948 at the Department of Pathology of the Royal Veterinary College. This "case material" does not include the material brought together by the present author, as it is well known that a very usual source of error in frequency studies is due to the fact that certain principles may prevail in selection when one is especially interested in a certain disease. Except a few cases the material is derived from Stockholm and the suburbs of that city. It is reasonable to presume that breed has no influence on the degree in which dogs are put to post mortem examination at the Royal Veterinary College.

From technical reasons it has been impossible to reach an exact conception of the distribution of the breeds within the mother population. The later has instead been estimated by means of a random sample among dogs licensed in Stockholm during the 13-year period 1938—1950: "The Stockholm material". During these years about 10.000 dogs a year have been licensed in Stockholm. The contribution has been achieved by means of a random sample of a yearly 2 % of these 10.000 dogs (in total 2.508 dogs). The confidence limits of the relative frequencies of the breeds in the "case material" have been determined by means of tables (*Hald*, 1948). The tables have not been sufficient as base of a determination of the relative frequencies in the mother population. The "error" in these frequencies has instead been approximately estimated by means of the "ordinary formula":

$$p \pm \sqrt{\frac{p(100\text{-}p)}{n}}$$

(p=the frequency in %, n=the total number of cases).

With reference to the large material, by means of which the mother population has been estimated, this approximation may be considered sufficient.

In order to compare breed distribution in the "Stockholm material" with that of the whole country the roll of The Swedish Kennel Club (S. K. C.) has been used.

The comparison between the observed frequency distributions has been done by means of χ^2-analysis.

It is more difficult to get a real picture of the age disposition in a post mortem material consisting of individuals who have died or been killed during different stages of the disease. In some cases the dog may have been killed in connection with the first attack while, in other cases, patient owners of dogs have let them go through several relapses. Years may have passed between those relapses. Thus, the material, used for the study of breed disposition, can not be considered sufficient in this connection. Instead the author has chosen to form his opinion about age disposition by means of studying how disc protrusions are distributed among different age groups in the material brought together by himself.

Results

Frequencies within different breeds

The first three columns of table 3 a show the distribution in percents on breeds of dogs in different materials. The three materials are characterized by the fact that the dogs have been chosen at random

TABLE 3 a.

Frequency of disc protrusions in different breeds.

	1 "Case material"		2 "Stockholm material"	3 "S. K. C-material"	4
Breed	% of the observed diseased dogs belonging to the breed (n = 100)	and the limits within which the corresponding theoretical value ought to be with a probability of 99 %	% of the observed licensed dogs belonging to the breed. Mean error. (n = 2508)	% of the observed dogs registered at SKC belonging to the breed. Mean error. (n = 69122)	Comparison between columns 1 and 2 χ^2-value. (d.f.[1] = 1)
Dachshund	52	63 —37 %	4.98 ± 0.44	9.20 ± 0.11	335.8***
French bulldog	8	16 — 2.5 „	0.32 ± 0.1	0.23 ± 0.02	81.4***[2]
Pekinese	7	15 — 1.9 „	2.03 ± 0.28	1.43 ± 0.05	8.8**[2]
Engl. bull dog	2	8.8— 0.1 „	0.32 ± 0.1	0.33 ± 0.02	3.4[2]
Great Dane	3	10.3— 0.3 „	0.92 ± 0.19	0.36 ± 0.02	2.4[2]
Pointer	2	8.8— 0.1 „	0.67 ± 0.17	2.47 ± 0.06	0.9[2]
St. Bernhard	1	7.1— 0.0 „	0.12 ± 0.07	0.39 ± 0.02	0.8[2]
Sealyham terrier	2	8.8— 0.1 „	0.72 ± 0.17	0.36 ± 0.02	0.7[2]
Swedish hound	3	10.3— 0.3 „	1.52 ± 0.25	16,26 ± 0.14	0.6[2]
Toy schnauzer	1	7.1— 0.0 „	0.99 ± 0.20	0.77 ± 0.03	0.3[2]
Rottweiler	3	10.3— 0.3 „	1.83 ± 0.26	1.84 ± 0.05	0.2[2]
Spaniel	4	11.6— 0.9 „	4.58 ± 0.41	5.48 ± 0.09	0.1
Maltese	1	7.1— 0.0 „	0.52 ± 0.15	0.24 ± 0.02	0.005[2]
Whippet	1	7.1— 0.0 „	0.39 ± 0.13	0.20 ± 0.02	0.004[2]
Poodle	1	7.1— 0.0 „	1.95 ± 0.28	2.11 ± 0.06	0.1[2]
Toy pincher	0	5.2— 0.0 „	0.76 ± 0.17	0.81 ± 0.03	0.1[2]
"Dachsbrache"	0	5.2— 0.0 „	0.28 ± 0.1	3.78 ± 0.07	0.2[2]
Collie	0	5.2— 0.0 „	2.11 ± 0.28	5.26 ± 0.08	1.2[2]
Mongrel	3	10.3— 0.3 „	8.89 ± 0.57	—	4.2*
Boxer	2	8.8— 0.1 „	7.77 ± 0.54	3.55 ± 0.07	4.6*
Spitz	0	5.2— 0.0 „	5.02 ± 0.44	4.53 ± 0.08	5.3*
Alsatian	3	10.3— 0.3 „	10.24 ± 0.61	12.82 ± 0.13	5.6*
Scottish terrier	0	5.2— 0.0 „	5.78 ± 0.47	1.36 ± 0.05	6.1*
Airedale terrier	0	5.2— 0.0 „	6.58 ± 0.5	3.28 ± 0.07	7.0**
Fox terrier	1	7.1— 0.0 „	16.86 ± 0.75	4.07 ± 0.08	18.7***
			Total comparison (d. f. = 9)		330.5***

1) among dogs examined post mortem at the Royal Veterinary College, which have been found suffering from disc prolapse: "case material"

2) dogs licensed in Stockholm during the period 1938—1950: "Stockholm material"

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[1] Degrees of freedom.

[2] These values are corrected χ^2-values (*Yates* correction).

3) dogs registered at the Swedish Kennel Club 1934—1948: "S.K.C.-material".

Mean errors have been given in columns 2 and 3. In column 1 confidence limits have been used instead of mean errors, because this material is rather small and the mean errors may consequently give a false representation of the limits between which the theoretical values might reasonably be placed.

The fourth column contains a series of χ^2-values. Each of those values is calculated for a fourfold table of the following type:

	"Case material"	"Stockholm material"
Dachshunds		
Others breeds		

It is easy to see that the χ^2-value in one row indicates how the difference between the percent figures in column 1 and 2, on the same row, should be perceived.

In the bottom of the fourth column is placed a χ^2-value representing the result of the total comparison of the distributions among breeds of the "case material" and the "Stockholm material". This value is too great to give the same theoretic distributions. Consequently, the disease should be more frequent in certain breeds than in others.

On reading the table one row after the other — the order of rows has been determined from practical reasons by the magnitude of the χ^2-values — we find that it is statistically highly significant that the disease is more frequent in the three breeds dachshund, french bulldog and pekinese than it should have been, had all breeds been equally disposed for disc degeneration.

It is difficult to reach a definite statement concerning other breeds, as the "case material" is relatively small. It is true that the fox terrier is obviously very scarce in the "case material", but this fact must probably be interpreted as an indication of the fact that this dog at least cannot belong to the most disposed breeds.

It is true that most of the dogs dissected at the Royal Veterinary College come from Stockholm. But certain animals derive from other parts of the country, and therefore one may suppose that it is not very remarkable that the "case material" is distributed among the breeds in a way that differs from the distribution within the "Stockholm material". In order to show that this fact alone gives no satisfactory explanation to the great differences observed in the distributions among breeds, a material from the roll of S. K. C. has been arranged in column 3. This "S. K. C.-material" is the only available instance of breed frequency in the whole country and it cannot pretend to be absolutely representative. However, it may be considered quite satisfactory in this connection.

According to *Joest*, e. i. should preferably afflict brown dachshunds. This observation, often cited in literature, will also be critically viewed. The "case material" used above will not be sufficient in this connection because data seldom are given in the records, concerning the colour of the hair. In the material, brought together by the author himself this factor has been taken into account.

Table 3 b does not support the theory that disc protrusions should be more frequent in a certain kind of dachshunds.

TABLE 3 b.

Frequency of disc protrusions in different kinds of dachshunds.[1]

	Brown smooth-haired	Black smooth-haired	Wire-haired and long-haired	χ^2-value (d. f. = 2)
Total number of investigated dogs	31	53	44	
Number of dogs with disc protrusions				
Absolute	9	23	15	1.93[2]
In per cent	29.0	43.4	34.1	

Frequencies within the two sexes

In the "case material" there are 51 male and 49 female dogs. The sex quota of this material is in other words as near 50 % as can reasonably be expected when chance alone is deciding. As it is however possible to suspect that the sex quota of the mother population may, from various selective principles, differ from the biological quota, this question has also been investigated. Within the "Stockholm material" 51.2 % were male, 48.8 female. There is no observed difference between the sex quotas of the "case material" and the "Stockholm material".

Frequencies within different age-groups

The values in table 4 a and b (the author's own material) and the graph of these (Fig. 2) show the percent of prolapse cases in different age-groups. Furthermore the material is divided into two breed groups — one the specially disposed breeds, in this work called the "chondrodystrophoid breed groups",[3] the other dogs who do not show more ob-

[1] The different groups of dachshunds used are commensurable as to age.

[2] The χ^2-analysis is a test of the hypothesis that the values in this row are distributed in the same manner as the values in the first row.

[3] The explication of this terme will be given on page 43.

TABLE 4 a.

Frequency of disc protrusion in different ages.

		< 2 months	2–9 months	1 year	2 years	3 years	4 years	5 years	6 years	7 years	> 7 years	Sum.	χ^2 values [1]
Chondro-dystrophoid dogs	Total number of investigated dogs	14	39	16	19	23	20	22	15	10	28	206[2]	
	Cases with disc protrusions												
	Absolute	0	0	0	0	4	11	12	8	7	21	63	89.25***
	In per cent	0	0	0	0	17.4	55	55	53.3	70	75	30.6	(d. f. = 9)
Non-chondro-dystrophoid dogs	Total number of investigated dogs	16	93	18	27	26	16	18	16	11	83	324[2]	
	Cases with disc protrusions												
	Absolute	0	0	0	0	0	1	0	1	4	21	27	72.40***
	In per cent	0	0	0	0	0	6.3	0	6.3	36.3	24.1	8.0	(d. f. = 2)

[1] The two χ^2-analysis are tests of the hypothesis that the values in these rows are distributed in the same manner as the values in the rows: "total number ...". The number of d. f. is only 2 for the latter χ^2-value, because the 10 columns are brought together to 3.

[2] For 31 dogs knowledge about the age is lacking.

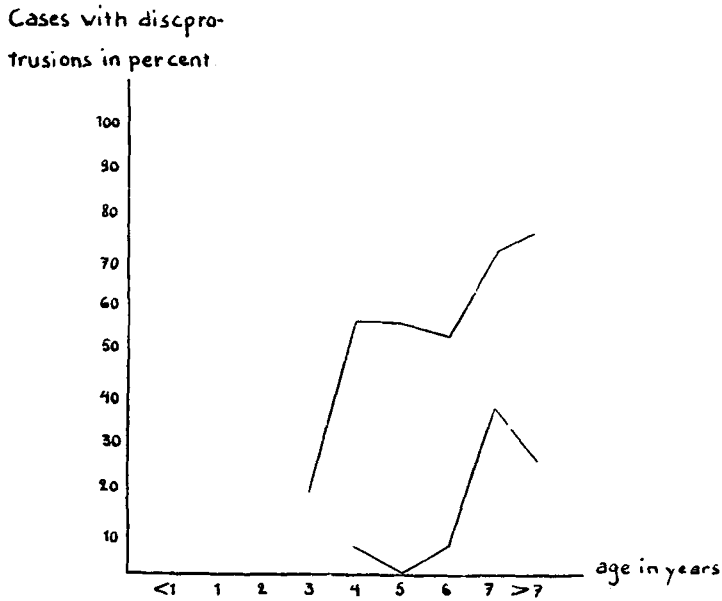

Fig. 2. Contents of table 4 a, shown diagrammatically. The upper curve concerns chondrodystrophoid, the lower non-chondrodystrophoid dogs.

vious chondrodystrophoid traits. The figures confirm the breed group disposition found in the other material and show rising frequency when the animals grow older. In the chondrodystrophoid breed group the first cases of prolapse appear already at the age of 3, in the other group at an age of 4 years. Is this a real difference? It is in fact not statistically significant. In the next chapter we will however find that the mean age of the cases where protrusions of type I has occurred, i. e. practically only chondrodystrophoid dogs, is statistically significant to be lower than that of cases of prolapses of type II (the figures are 5.78 and 8.77 respectively) and that also other manifestations of disc degeneration appear much earlier in the former group.

TABLE 4 b.

Frequency of disc protrusions in different breed groups.

	Chondrodystrophoid dogs	Non-chondrodystrophoid dogs	χ^2-value (d. f. = 1.)
Total number of investigated dogs	206	324	
Number of dogs with disc protrusions			
Absolute	63	27	44.15*** [1]
In per cent	30.6	8.0	

[1] The χ^2-analysis is a test of the hypothesis that the values in this row are distributed in the same manner as the values in the first row.

The meaning of breed disposition

Which is the common denominator of the exposed breeds?

The most interesting finding during the study of the frequency of the disc degeneration in dogs of different breeds, sexes and ages is undoubtedly the strongly pronounced disposition of the three breeds french bulldog, dachshund and pekinese. This fact indicates that a disposition factor of a constitutional character exists concerning this disease. How then does this constitutional factor manifest itself, which ought consequently to be a common denominator of the breeds in question and which should preferably be missing in other breeds?

The breed connection has been observed since long ago, though no real statistical study has before been made on the subject. This affords an explanation of the fact that to an overwhelmingly high degree e. i. has been regarded as a special peculiarity of the dachshund breed and that this has been the reason why the disproportion between length of back and height of body in this breed has been considered so important. Also, the common german name of the disease is "Dackellähmung". The high relative frequency of the disease in french bulldog is however a powerful argument against the primary importance of the abovementioned mechanical factor, which is missing in the latter animal. In order to penetrate this problem it was found desirable to procure an idea of the relation between length of back and height of body in the three breeds concerned and in some of the others. The most appropriate measure was found to be the size — a denomination used in zootechnics. The size is defined as the relation between the length of the trunk measured from the point of the shoulder to the *tuber ischiadicum* and the height at withers. The measurements have been performed on 121 dogs from the breeds contained in table 5. In dog the size is as a rule low-rectangular but in some breeds it is very closed to the square type. Among the dogs of the present material french bulldog, alsatian,

TABLE 5.

The mean of the relation length of trunk/height at withers in certain breeds.

	$\bar{x}$	range	n
Swedish hound	1.04	1.00—1.09	14
French bulldog	1.10	1.03—1.15	7
Elkhound	1.12	1.06—1.17	5
Alsatian	1.13	1.08—1.25	23
Spaniel	1.25	1.09—1.37	21
"Dachsbrache"	1.37	1.28—1.52	7
Skye terrier	1.66	1.52—1.80	6
Pekinese	1.72	1.55—1.94	7
Dachshund	1.85	1.67—2.00	31

swedish hound and elkhound were nearly square, "Dachsbrache" and spaniel moderately and skye terrier, dachshund and pekinese very low-rectangular.

The figures and the problem do not require the use of statistical methods in this connection. The table shows clearly that a very low-rectangular size is not the common characteristic of the breeds disposed for disc degeneration.

Common to these breeds, however, is their dwarfishness. *Fankhauser* (1948) has suggested that the disposition towards disease of the discs might be referred to the same basic causes as the short- and bandy-leggedness and *Pommer* (1937) has suspected the existence of endocrine disorders. *Stockhard* (1941) has experimented with dogs during a series of genetic investigations. According to *Stockhard* no other mammal shows as great discrepancies in its constitutional type as does the dog, showing a medley of breed types from dwarfs that weigh less than 1 kg to giants of nearly 100 kgs. Many of these types are characterized by the same properties as certain extreme and even pathological conditions in man. We may thus find well proportioned giants (Irish wolfhound and Great Dane) and acromegalic giants (St. Bernhard, bloodhound and New Foundland). *Stockhard* also was able to point to certain modifications in the hypophysis of these acromegalic breeds thus connecting to Pierre-Marie's observation on the connection between acromegaly and hypophysis. The dwarf breeds, which are much more common, may also be divided in two groups, viz. well proportioned (atheliotic) and chondrodystrophic (achondroplasic) animals. To the former belongs e. g. pincher and to the latter french bulldog, pekinese, dachshund, King Charles, Boston terrier and others.

Presentation of the notion chondrodystrophia

By chondrodystrophia or achondroplasia is meant an anomaly in the skeletal development. Its morphological essence is a disturbance in endochondral ossification. Thus the disease manifests itself as changes in the cartilage-preformed parts of the skeleton. Owing to a retarded and prematurely stopped ossifying process, that chiefly takes place in the tissues that possess the greatest growth energy, viz. the diaphyses of the long bones (*Wilton*, 1933), achondroplasia results in disproportionally short extremities. They show characteristic deformations chiefly through enlargement of the epiphyses and screw-like course of the trabeculae. This checking of the growth of cartilage-preformed bones also concerns the base of the skull and results in a retraction of the root of the nose. The chondrodystrophoid dwarf is consequently a disproportional individual with short deformed legs, big head, saddling deformity of the nose and comparably big hands and feet, often with phalanges of uniform length.

Individuals carrying these signs of an abnormal skeletal development may die soon after birth or grow up as dwarfs. Chondrodystrophia is the most common cause of dwarfishness and has been known since ancient times. The egyptian god Bes, the mediaeval court jesters and the circus dwarfs of our days owe their tragi-comical popularity to chondrodystrophia. Also chondrodystrophic traits have been regarded as race characteristics in certain dwarf peoples, e. g. the pigmies (*Gusinde*, 1937).

Many suggestions have been made on the cause of this abnormal development of the skeleton. *Glisson* (1650) was the first author who described chondrodystrophia. He considered it to be a foetal rickets. The discussion pro et contra this theory lasted until *Kaufmann* published his work in 1892. He rejects the thought of an intrauterine rickets. The alternative most attended to during the intervening period was *Virchow*'s (1853) equality sign between cretinism and chondrodystrophia. *Dieterle* (1906) and *Sumita* (1910) rejected this possibility and showed that the thyroid gland had nothing to do with the genesis of the disease. *Dietrich* (1921) found abnormally small parathyroid glands in chondrodystrophic individuals.

In his interpretation of the pathogenesis of chondrodystrophia foetalis *Wilton* (1933) was able to present arguments based on histological observations indicating that the oldest theory might be right. Doing this *Wilton* directed the suspicions against the same causal factor as that of rickets, viz. insufficiency of the parathyroid glands, D-avitaminosis and lack of certain inorganic salts. In 1946 *Studitskii* maintained that his experimental investigations indicated that D-avitaminosis was of primary importance. *Studitskii* considered that the lack of vitamin D should cause chondrodystrophia by means of an increase in the function of the foetal parathyroid gland. *Landauer* (1946) is of the contrary of the opinion that if anything at all is certain concerning the cause of achondroplasia it is the fact that humoral factors can not be involved. The discussion on the etiology of this skeletal abnormity is far from finished. It seems that current research works along two lines, one concerned with humoral factors, especially of endocrine nature, the other concerned with hereditary factors. The type of chondrodystrophia found in calves of the Dexter breed was, it is true, considered as dominantly hereditary by *Crew* (1924), though he thought it probable that the disease was caused primarily by a hypoplasia of the front lobe of the hypophysis. The same conception had been reached by *Adametz* (1925) independent of *Crew*, and *Dunn* (1946) had succeeded to make a case of achondroplasia in man to react favourably to a peroral administration of extract from front lobe of hypophysis. Furthermore *Silberberg* (1936) had been able to prove that an injection of hypophysis extract furthered the endochondral ossification in guinea pigs and that this process took place without the mediation of the thyroid gland. This principle, which comprehends constitutional-hereditary and humoral factors, is also found in the works of *Stockhard*.

Chondrodystrophia as a definitely pathological phenomenon has been described in animals as well as in man. These descriptions comprehend among other animals cattle (*Müller* 1861, *Crew* 1924), dog (*Regnault* 1901), rodents (*Brown and Pearce*, 1945) and birds (*Landauer and Dunn*, 1926).

The question is being discussed whether certain disproportionally built dwarfish breeds might be characterized as breeds by chondrodystrophoid traits. *Joest* (1921) joins a statement by *Bormann* (1911) that it can not in any way be considered as proven that the shortleggedness in certain domestic animals should be assigned to a chondrodystrophoid constitution. *Dexler* (1927) also reacts against this idea. *Adametz* considers that disproportional dwarfishness (achondroplasia) is a consequence of a breed creating mutation and exists in certain breeds of cattle, swine and dogs. *Fairbank* (1949) writes:

"Achondroplasia undoubtedly occurs in certain animals, but it is no longer regarded as a satisfactory explanation for the stunting of limb growth in all short limbed species".

When dog is concerned already *Regnault* speaks for the thought that achondroplasia should be a breed characteristic of the dachshund. *Kronacher* (1928) and *Murciani* (1936) takes the same standpoint. *Stockhard* (1941) regards french bulldog and pekinese as genuine chondrodystrophics. To other breeds, among those the dachshund, he attributes a localized achondroplasia. It is well known that achondroplasia may also manifest itself in such relatively low degrees. Thus *Dietrich* 1929 writes:

"Gegenüber diese äussersten Missgestaltungen des Körpers kommen jedoch auch Fälle von Chondrodystrophie mit geringeren Veränderungen, vor allem im Bereiche des Kopfes. Es ist da nur die Kürze der Gliedmassen auffallend".

Stockhard himself sees the problem in the following way:

"Aside from the fully typical condition, every degree of variation in achondroplasic growth is met among human beings, and slight expressions in this direction give very sturdy persons with a determined demeanor".

Zondek (1948) mentions localized achondroplasia with changes only in the arms, especially in the humerus. At last *Adametz* gives the matter the following commentary:

"Gleich vielen anderen Mutationen besitzt diese Art von Zwergwuchs die Eigentümlichkeit, dass sie in allen möglichen Graden der Ausbildung auftritt. Vom nahezu normalen Individuum, dessen nur durch eine gewisse Kurzgliedrigkeit angedeutet Zugehörigkeit zur Gruppe disproportionierten Zwerge allein das geübte Auge erkennt, über den bereits deutlich als Achondroplasten gekennzeichneten, disproportionierten Zwerg bis hinab zur lebensunfähigen, entweder abortierten oder bei der Geburt sterbendem Form höchsten Grades der Achondroplasie, gibt es alle denkbaren Übergänge".

Interesting in this connection is the fact that *Staffe* (1947) gives as the real argument for the thought that micromelia as a breed characteristic should be a manifestation of chondrodystrophia the disposition of the dachshund for "*enchondrosis intervertebralis*"!

Even if the argumentation in literature for the existence of chondrodystrophic traits especially in the three breeds of interest to the present work, french bulldog, dachshund and pekinese is rather conclusive, some complementary observations might be desirable, as it is rather remarkable that no mention whatever has been made of investigations on the histology of the endochondral ossification in these breeds. Such an investigation should provide the surest way to obtain an answer to the question.

Present investigations on the endochondral ossification

The question has been formed as followed: Do the three breeds french bulldog, dachshund and pekinese differ from other dogs of more ordinary breeds by showing histological signs of an modification in the endochondral ossification coinciding with that described in connection with chondrodystrophia?

Material and methods. In order to obtain an answer to this question the author has examined costo-chondral junctions from the middle ribs and epiphyses from humerus, femur and bodies of the vertebrae in a material of 23 new-born puppies. These are distributed among different breeds in the following manner:

Dachshund	5	Shetland sheep dog	1
French bulldog	5	Border terrier	1
Mongrel	4	Fox terrier	1
Afghanian	1	Poodle	1
Boxer	1	Rottweiler	1
Collie	1	Scottish terrier	1

Decalcification according to Perényi, staining with hematoxylin-picric acid fuchsin (van Gieson) and for calcium hemalum-eosin according to Bock.

The nomenclature concerning endochondral ossification follows the principles, given by *Ham* (1950).

Results. The available material may be divided in two groups with reference to the morphology of the endochondral ossification, one consisting of french bulldogs and dachshunds and the other all the rest. These latter show, with certain modifications, the picture that is characteristic of ordinary endochondral ossification (Fig. 10). The zone of resting cartilage usually shows the picture of a young hyaline cartilage, which passes into a zone of proliferation with the cells arranged in regular columns. The following cartilage, the zone of maturing cartilage is well developed and has maintained its column structure. The intercellular passages between these rows of maturing cartilage cells are regular and nearest the diaphysis mostly calcified to a high degree. The border on the diaphysis is even and the latter is characterized by long and narrow trabeculae, built on the calcified intercellular passages ("direction columns") of the zone of maturing cartilage. The vessels situated in the cartilage are surrounded in its diaphyseal part by an osseous tissue built on the cartilage and in the part more distant from the diaphysis by a relatively immature osteoblastema. In most cases the picture is most exemplary and gives the impression of a very regular ossification.

From these dogs with their model endochondral ossification the group containing french bulldog and dachshund differs most obviously (Fig. 11). The difference is so conspicuous that it is possible to discern this group with few exceptions from anonymized slides. The zone of resting cartilage in the two groups do not seem to show any significant difference. In both it is possible to observe rather great variations in the degree of maturity of the resting cartilage. In the new-born puppy this zone of resting cartilage most usually seems to be a young hyaline cartilage, but many times and irrespectively of breed it looks rather immature, nearly embryonary. From the moment when the cartilage begins to prepare itself for the ossification process the picture in the group french bulldog—dachshund shows quite a number of divergences from or modifications of the ordinary picture outlined above.

The transition from resting cartilage into the zone of proliferation is often contourless. The greatest part of the proliferation zone is usually a rather confused zone of vividly proliferating cartilage cells which have formed themselves into distinctive columns only within a comparatively narrow belt. Cells and nuclei of cells in these rows many times do not show the typical discoid arrangement. The zone of maturing cartilage is not narrower or broader than in other dogs. Reduced calcification of this zone is, however, rather common. The intercellular passages between the columns show a certain irregularity in form. It often seems as if only the broader passages serve as "direction columns". The border on the diaphysis is rather uneven with, in most cases, descending cartilaginous buds and bone marrow vessels penetrating deeply into the cartilage. These bone marrow vessels are conspicuously numerous. They rather regularly surround themselves with an immature osteoblastema, which is often strongly hyperaemic. The descending cartilaginous buds often consist of several rows of cartilaginous cells with sometimes unopened capsules. On some occasions it has been observed how such cartilaginous buds have been separated and exist as isolated cartilage islands in the diaphysis (Fig. 12). The ossification itself, based on the "direction columns" is in ordinary cases characterized by a vivid activity of osteoblasts around the latter. In the group french bulldog—dachshund the activity of the osteoblasts many times does not seem to be very pronounced and in these cases it is possible to see a conspicuously great proportion of "osteoclasts". The new-formed trabeculae are short and thick as distinct from the case in other dogs, also those of the dwarfish breeds. In those dogs they are always long and slender with a parallel course.

The above-described course of the endochondral ossification in french bulldog and dachshund may, also to certain, lesser extent be recognized in the epiphyses of the bodies of the vertebrae. In this case the difference is far more subtile and hardly permits a grouping of anonymized slides.

Discussion

The purpose of this morphological examination of some breeds of dogs has already been explained: Do the breeds specially disposed to disc degeneration show any histological signs of a modification of the endochondral ossification according to that described in connection with chondrodystrophia?

During his studies of chondrodystrophia *Wilton* was able to observe characteristic changes in all zones of the epiphyseal cartilage. The inner layer of the perichondrium was broadened and richly vascularized and held a great number of chondroblasts perivascularily. The resting cartilage was of embryonary type, richly vascularized and sparse in intercellular substance. *The column arrangement in the proliferation zone was weakly developed, if marked at all.* Instead a vesicular degeneration of the cartilage was found. Finally extreme changes were observed in the ossification line itself. It was very uneven because of the fact that bone marrow vessels intruded deeply into the cartilage. These vessels were surrounded by cells reminding of fibroblasts, which changed into an osteoblastema without any sharply defined interval. Along these vessels and in the diaphyseal portion of the cartilage osteoid was formed.

The change in the proliferation zone has been stressed because this fact above all seems to have characterized the histological picture of chondrodystrophia as seen by different authors. *Meyenburg* (1938) is particularly impressed by the unsatisfactory development of the proliferation zone, especially of the column structure. *Bennett* (1948) states that the primary injury is wholly or for the most part localized to the proliferation zone. In this zone the cells do not form rows and do not pass the normal stages of proliferation, maturation and regression. The invasion into the cartilage of the bone marrow vessels is erratic and irregular masses of cartilage are formed with irregular calcification and ossification. As far as the animals are concerned the histological picture in chondrodystrophoid calves has been described. *H. Müller* (1860) showed that the basic trait of the disease was a disturbance of the endochondral ossification. *Crew* and *F. Müller* (1937) have both paid most attention to the change in the proliferation zone. Thus Müller states:

"Die Zone des ruhenden Knorpels und die Zone des mässig wuchernden Knorpels Zeigen keine vesentlichen Veränderungen. Die Zone der Gerichteten Knorpelsäulen ist hochgradig verschmälert und streckenweise fehlend".

To sum up the results of the author's investigation described in the above the group of the french bulldog and dachshund seems to differ from other dogs mainly with reference to the formation of the proliferation zone and the ossification line itself. Most conspicuous are the weak development of the column arrangement in the proliferation zone, the uneven and irregular line of ossification and the "osteoclasis" in the diaphysis. The difference is not great but it is unmistakable. Of course it is not possible to expect that the normal endochondral ossification found in some breeds should tally completely with the pictures in purely pathological individuals. One might possibly allow for a modification of the picture. The modification of the picture found in french bulldogs and dachshunds seems to show a tendency towards the histological changes that characterize chondrodystrophia.

Of course it must be asked if this picture might be considered possible in some other form of dwarfishness. The only differential diagnostic alternative in this connection is cretinism. Considering that the demarcation between these two types of dwarfishness is not very clear and that the basic endocrinic factors of chondrodystrophia as well as of all the breeds in question have not yet been satisfactorily examined, the author will not now discuss this question.

Supported by authoritative statements in literature and his own investigations, the author is going to use the denomination "chondrodystrophoid breed group" [1] in connection with the group of dogs that have, according to the present statistics, shown themselves to be particularly exposed to disc degeneration. The author is well aware of the fact that much remains yet to be found before the chondrodystrophoid character of these breeds might be established. Further morphological and endocrinological investigations would surely result in a better understanding of this problem.

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[1] Breeds lacking more conspicuous traits of chondrodystrophia will be brought together as "non-chondrodystrophoid breeds".

Chapter V

MACROSCOPICAL INVESTIGATIONS

Introduction

This study on the pathological anatomy of the discs has been made with special reference to the conditions connected with the disease that has long been called e. i. In the general introduction it was mentioned that the clinically important changes in this disease were protrusions from the discs made possible by degenerative changes in the latter. Owing to the fact that the changes have often been found to be multiple and relatively common even in cases which do not show any clinical symtoms a comprehensive and systematic investigation has been found desirable, as it seemed very probable that this disease in the discs might be a systemic disease. From the study of disc degeneration in man we well know that the discs are subject to certain changes from age group to age group. This fact gave further emphasis to the desirability of a systematic investigation in order to obtain an answer to all the questions that presented themselves. In the statistical study the author has used the dorsal disc prolapses as indicators of disc degeneration. In the following chapter the author will try to give an explanation of the relationship between prolapse and degeneration based on morphological studies.

Material and methods

561 dogs distributed among breeds and ages according to table 6 have been examined. This material consists of dogs dead or killed on account of various diseases. The material has been selected in such a way that clinically manifest cases of disc degeneration have of course been brought to examination to a greater extent that usual and from a relative point of view more than any other disease, and furthermore, the breeds dachshund, French bulldog and pekinese have been over-represented.

The examination has been performed in the two following ways:

1) After a customary post mortem on the animals the vertebral column has been relieved as far as possible from muscles and ribs,

TABLE 6.

Investigated dog material.

Breed group	< 2 months	2–9 months	1 year	2 years	3 years	4 years	5 years	6 years	7 years	> 7 years	Age unknown	Sum.
Chondro-dystrophoid [1]	14	39	16	19	23	20	22	15	10	28	5	211
Non-chondro-dystrophoid [2]	16	93	18	27	26	16	18	16	11	83	26	350

except the front and back pairs of ribs which have been left remaining as points of orientation. Then the spinal cord has been laid bare by means of cutting away the vertebral arches. When the preparation thus obtained has been fixed in a 5 % formaldehyde solution during 24 hours the spinal cord has been removed from the vertebral canal. By means of this slight fixation the spinal cord and the vertebral canal have been fixed to an extent that has made it easy to inspect and describe eventual prolapses and corresponding impressions. Finally every disc has been examined after vertical cuts perpendicular to the longitudinal direction of the vertebral column (Fig. 3). The observed changes have been traced on a record (Fig. 1). As has earlier been pointed out the discs have been numbered from 1 to 26 and these numbers have been used instead of the more circumstantial phrase: the disc between this and that vertebra.

The vertical section (A) through the disc has been made cranially to the centre of the disc, which has caused the main part of the disc to remain on the behind vertebra. After inspection and description the disc and part of the body of the vertebra have been removed by means of a pair of bone cutting forceps (section B) and the preparations have been placed in various fixation fluids. It proved very difficult to fix the discs completely isolated from their organic connection with the bodies of the vertebrae. A. f. showed a tendency towards shrinking and n. p. a tendency towards swelling. As isotonic fixation fluids usually were

[1] Including except Dachshund, French bulldog and Pekinese also Spaniel and "Dachsbrache" being closely related to the former regarding the normal age development of the discs and the nature of disc degeneration (see p. 57).

[2] Afghanian, Airedale terrier, Alsatian, Border terrier, Boxer, Chow-Chow, Collie, Dalmatian, Dobberman pincher, Elkhound, Fox terrier, Great Dane, Irish Blue terrier, Labrador, Lakeland terrier, Maltese, Mongrel, New Foundland, Old English Sheepdog, Pointer, Poodle, Rottweiler, Russian greyhound, Schnauzer, Scottish terrier, Setter, Skye terrier, Spitz, St. Bernhard, Swedish hound, Welsh terrier, Whippet, Vorsteh and different kinds of toy breeds.

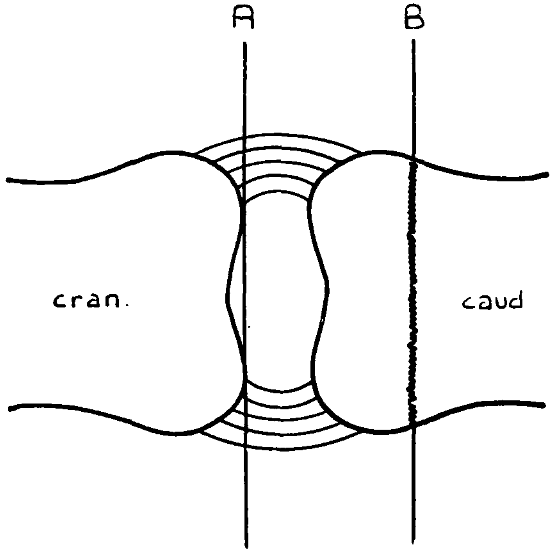

Fig. 3. Outline of the method of taking histological preparations.

too weak or showed other disadvantages this method with the disc resting on one of the epiphyses of the body of the vertebra resulted in the least deformation of the preparation. The remaining part of the body of the vertebra has been split along the sagittal plane in order to examine existing intraspongious prolapses. The method described above has been used on 251 backs.

2) In the remaining 310 cases the discs have been examined after cutting through the vertebral column sagittally and otherwise the same preliminaries have been made as in the method described above.

In certain cases the ruptures in the discs have been examined by means of X-rays. In that respect discography has been used with thorotrast as contrast medium. The method used is principally the same as that described by *Lindblom* (1948).

Statistical methods used in this chapter are analysis of variance and χ^2-analysis.

The dorsal disc protrusions

General commentary on localization

In 93 of the examined 561 cases prolapses have been observed, distributed among different ages according to table 4 a. The prolapses are solitary or multiple and are distributed along the vertebral column as shown in the histogram, Fig. 4. This histogram illustrates the distribu-

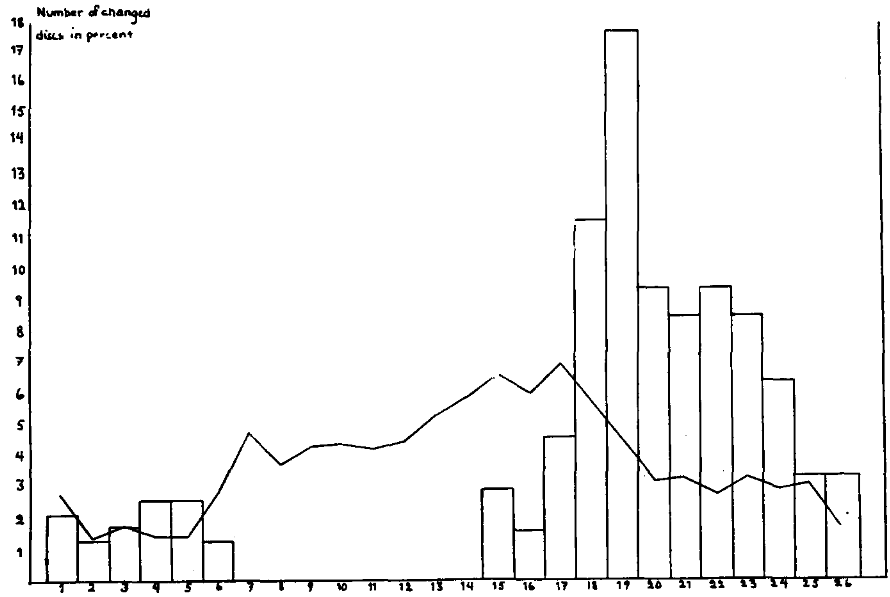

Fig. 4. Distribution of disc protrusions and of disc calcification within the vertebral column. The histogram shows the distribution of protrusions, the curve that of calcification.

tion among the different discs of 232 prolapses from these 93 cases, i. e. circa 2.5 pr case. The abscissa stands for the vertebral column with the discs numbered as has been described. The histogram contains three sectors: a cervical region showing a comparatively low frequency of prolapses, a thoracic region where no prolapses are to be found and finally a thoracolumbar region which shows the greatest frequency.

In Fig. 5 all prolapse cases are presented together in order to show how the changes are distributed along the vertebral column in each single case. This figure and the histogram may be brought together in the following table:

TABLE 7.

Frequency of disc protrusions in different regions of the vertebral column.

Localization of the protrusions	Number of cases abs.	Number of cases rel. (in %)[1]	Number of cases abs.	Number of cases rel. (in %)[1]
Cervical	3	3.2 ± 1.8	15 (Cervical and Cervical + thoracolumbar)	16.1 ± 3.8 (Cervical and Cervical + thoracolumbar)
Cervical + thoracolumbar	12	12.9 ± 3.5	90 (Cervical + thoracolumbar and Thoracolumbar)	96.9 ± 1.8 (Cervical + thoracolumbar and Thoracolumbar)
Thoracolumbar	78	83.9 ± 3.8		

[1] The error in the percent figures has been determined in the same manner as in table 3 a.

Fig. 5. Location of the disc protrusions in the vertebral column for each single case.

Cervical protrusions

15 cases showing cervical disc prolapses have been observed, 12 of which did also show prolapses in the thoracolumbar region. Concerning the three remaining cases one (case number 8, Fig. 5) showed 1 prolapse. Prolapses in the cervical region are thus rather scarce in this material and are most often found together with thoracolumbar prolapses. It is very uncommon to find that the only disc prolapse in a case is located to the cervical region (1 case in the present material).

That the changes connected with disc degeneration and disc prolapse may also take place in the cervical region is a well known fact in man as well as in dog. *Junge* (1950) observes that the cervical region is next to the lumbar region when the frequency of disc protrusion in man is concerned. *Joest, Hutyra—Marek* and *Frauchiger—Fankhauser* observe that the changes connected with e. i. may also be localized to the neck, though this is very seldom the case. Casuistic observations on clinically important cervical disc prolapses in dog have however, with one exception, been lacking in literature. *Olsson* (1951 b) describes a case of cervical disc protrusion successfully operated upon by means of disc fenestration.

Among the present 15 cases of cervical disc prolapses there are two in which the anamnesis mentions symptoms that might be derived from those prolapses. Among the 100 cases of the disease that are available to the department from the time preceding this investigation there are 9 cases in which the clinical symptoms may be correlated to post mortem findings of cervical disc prolapses. Of course the cervical disc prolapses show a different clinical picture than that of the thoracolumbar ones. A casuistic report on these cases which would be very interesting in itself does however not belong to the scope of this work. In chapter VII, however, such a case will be mentioned.

The lack of protrusions in the region of the discs 7—14

In this region none of the observed 232 prolapses has been located. The probability of finding a prolapse in this region is between 0 and 2.5 % (with 99 per cent confidence limits). The practical probability seems however to be 0 if the special anatomic arrangements in this sector are considered which have been accounted for in chapter III. *That lig. conjugale cost. is really an important protective mechanism to the spinal cord is shown by the fact that premisses for prolapses in the form of degeneration of nucleus or annulus and ruptures of the annulus are of common occurrence also in this sector* (Fig. 13).

Observations on disc prolapses in dog in this sector are also lacking in literature. However, casuistic observations on man report such cases even in the region of the sternal ribs (*Bradford and Spurling* 1945, *Müller* 1951 and others). As has already been mentioned the equivalent in man to *lig. conjugale* *cost.*, viz. *lig. capituli costae interarticulare* is not able to give the spinal cord the same protection against eruptions from the discs. The thoracic localization of the disc prolapses in man seems however to be the one that is most uncommon (*Bradford and Spurling, Junge*). *Bradford and Spurling* consider that this is not surprising as the discs in this region are thinner, the volume of n. p. lesser and the movements more restricted than elsewhere in the vertebral column.

Thoracolumbar protrusions

Figures 4 and 5 show the dominant rôle of this part of the vertebral canal. Thus, of the 93 cases thoracolumbar disc prolapses have been observed alone or together with cervical ones in 90 cases. The probability of finding the prolapse or prolapses in a case of disc prolapse in dog in the thoracolumbar region is thus statistically ascertained to be greater than 91.5 %. As the thoracolumbar region is twice as big as the cervical one the frequency should be twice as great too if chance alone was the deciding factor. The frequency is about five times greater.

The histogram shows also that disc 19, i. e. the one between Th. 13 and L 1 has been the disc that has been subject to the greatest number of disc protrusions. It is interesting to compare the predilection places of disc degeneration in man and dog. For this reason a diagram is reproduced in this work from a paper of *Friberg and Hirsch* (1949) (Fig. 6). If the diagrams are placed facing each other they seem to reflect each other almost exactly. The material referred to shows the predominance of the discs L 4—L 5 and L 5—S 1. This difference as to predilection place is of importance from a comparative medical point of view. It determines the clinical manifestations of the disease. In dog the clinical picture is characterized according to the localization, especially by a compression of the spinal cord. Initial symptoms and relatively slight cases show greater similarities to lumbago in man than do the serious cases in which the picture is characterized by paraplegia or, in exceptional cases, by monoplegia. The sciatic syndrome that is the most important serious expression of disc degeneration in man is practically negligible in dog.

The reason for this difference in the localization of the disc degeneration does of course depend on the localization and type of the mechanical stresses to which a horizontal spinal column is subjected as distinguished from those stresses which have resulted from the upright posture of man. That the low back in man is the part of the back which carries the heaviest load seems to be an almost axiomatic fact, which has been testified in several works (*Bradford and Spurling, Splithoff*, and others). In chapter III an account has been given of the conceptions which have appeared in literature concerning the mechanical features

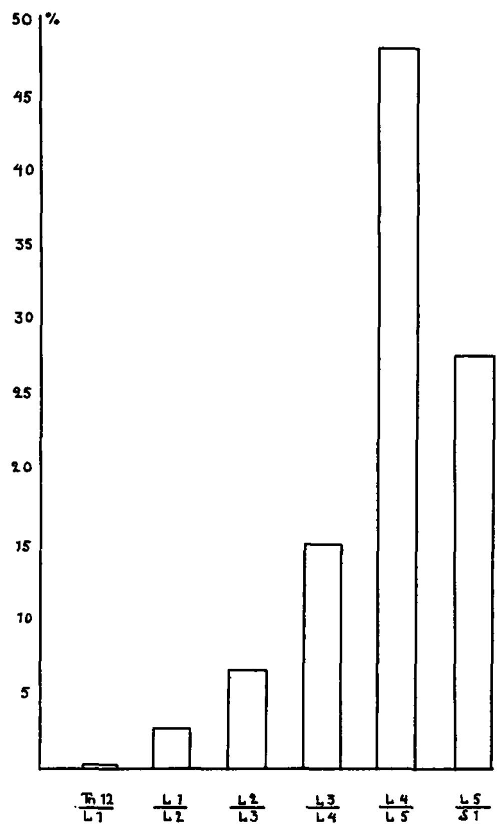

Fig. 6. The site of lumbar disc degeneration in man (*Friberg and Hirsch*, 1949).

of the spinal column in dog. The question of the connection between the localization of mechanical stresses and the disc degeneration will be discussed later on after an account has also been given of other types of disc degeneration.

The table on the 93 prolapse cases with the localization of the changes in the vertebral column (Fig. 5) gives some morphological facts of practical clinical interest. As *Olsson* has pointed out the size, localization and number of the thoracolumbar prolapses do not seem to determine the clinical disease picture as much as the manner in which they originate and their dynamics as a whole. Unfortunately the available clinical data do not permit a satisfactory evaluation of these circumstances. But the material seems to give some information on the frequency of prolapses of the different discs, which may be of a certain value to the diagnosis. In the following comparison an endeavour has been made to show the probability of different discs or disc groups as seat of protrusions.

TABLE 8.

Frequency of disc protrusions in different parts of the thoracolumbar region.

Localization of the protrusions	Number of cases Abs.	Rel. (in %)
Disc 19	41	45.6 ± 5.3
Discs 18—20	63	70 ± 4.8
» 17—21	75	83.3 ± 3.9
» 22—24	39	43.3 ± 5.2
» 22—26	43	47.8 ± 5.3

In thoracolumbar localization it is statistically highly significant that the probability of finding the prolapse in the portion of the discs 17—21 is more than 71.6 %.

Of the 90 cases of thoracolumbar localization 54 (in per cent 60 ± 5.2) have shown more than one prolapse. Among these 54 multiple prolapse cases 36 (in per cent 66 ± 6.4) have had the prolapses in discs immediately adjoining to each other. Thus it is statistically highly significant that the probability of finding the prolapses in adjoining discs is more than 46.8 %. Thus 36 cases of only one prolapse have been observed (in per cent 40 ± 5.2). Between the percent figures of cases with multiple and solitary protrusions respectively (the difference is 20 ± 7.3) a significant difference has been found to exist.

The macroscopic morphology of the protrusions and the concerned discs. Subdivision in two types of prolapse

The macroscopic appearance of the protrusions varies mainly along two lines, which circumstance has earlier been mentioned (*Tillmanns*, *Fankhauser*, *Riser*). In Fig. 5 this subdivision in two types has been marked out.

Type I. Protrusions of this type will usually be of considerable size, covering the major part of the profile of the vertebral canal (Fig. 14) or, if the expansion has been horizontal it may cover the length of one vertebra. The prolapse is sometimes found to be cushion-shaped, as broad as the bottom of the vertebral canal and extending somewhat cranially and caudally to the disc, its height often being more than half the height of the vertebral canal (Fig. 16). When the expansion of the prolapse has been horizontal, the dorsal surface of the disc may be covered by the prolapse completely or only on one side. This expansion may take place in the cranial or in the caudal direction. The protruded disc material often will be tightly pressed against the bottom or sides of the vertebral canal. Prolapses which are mainly laterally localized may sometimes reach the dorsal surface of the spinal cord and form a vault over it (Fig. 15). When extending cranially these lateral protrusions may fill the *for. intervertebrale* more or less completely. (As the *incisura vertebralis caud.* is considerably deeper than the cranial one major parts of the intervertebral foramina will be localized cranially to the discs concerned.)

Protrusions of this type are also characterized by an uneven granulated surface which adheres fibrinously or fibrously to the *dura mater spinalis.* The shape of the prolapses is irregular and their consistency often brittle and grainy, sometimes plaster-like. Their colour varies from white-yellow or grey-yellow to grey-red. The variations in colour is mainly a function of the strength and duration of the reactive inflammation released from the epidural space. In those cases where a huge eruption of disc tissue has taken place a strong inflammatory reaction is the rule. In acute cases this inflammation is characterized by hyperaemia, oedema and spread haemorrhages, and some times also a subdural haemorrhage is observed in connection with the protrusion. This haemorrhage is not always localized only to the area concerned but may also extend cranially. *Olsson* has observed that these cases which may often lead ad mortem showing the disease picture of spinal shock give a characteristic myelogram with successive change to a total blocking of the liquor passage. When the acute inflammatory symptoms have decreased the colour becomes more grey-yellow and the consistency somewhat firmer.

As has been mentioned above prolapses of type I are of considerable size. Their connection with the inner part of the disc through ruptures of the a. f. will be discussed later on. In many cases it has been observed that the disc in question is narrower than the neighbouring ones. A statistically highly significant difference has also been found between prolapsed discs and corresponding discs from other cases. An analysis of variance on this fact is shown in the following table.

TABLE 9.

Analysis of variance of the length of corresponding discs in cases with and without protrusions.

Source of variation	Sum of squares	Degrees of freedom	Mean square
Between cases with and without protrusions	9.40	1	9.40
Within cases with and without protrusions	12.87	25	0.51
Total	22.27	26	

$$\text{Ratio of mean squares } \frac{9.40}{0.51} = 18.43^{***}$$

In order to make possible an estimate of the degree and significance of progressive processes in the prolapsed discs an objective volumimetric study might perhaps have been of interest together with pressure measurements on the discs during normal and pathological conditions. However, technical difficulties have made this impossible at least for the time being.

Regarding the cut surfaces of discs showing prolapses of this kind the following can be stated. *In all these cases it is possible to find very extensive regressive changes in the interior of the disc* all of them sometimes combined with a change of the n. p. from the normal kidney-shape to a pear-shape. Their macroscopic appearance mostly follows one of the three following patterns. By far the most usual in prolapses of type I is a total or partial calcification of n. p. and the inner layers of the a. f. (Fig. 17). Among all protrusions of type I in the present material this calcification has been found twice as often as other kinds of degeneration taken all together. The centre of the disc is changed into a white substance that looks like chalk or plaster. If the calcification is partial the change will more often take place in the peripheric parts of the n. p. Other macroscopic signs of disc degeneration in this kind of prolapses is the yellow-grey rather dull cut surface of the n. p. and decomposition of the central parts of the disc into a greyish brown or often dirty-brown disintegrated substance. This latter kind of degeneration has been observed in about a third of the cases showing protrusions. *It is interesting that this kind of degeneration has only been observed in the present material in such cases where the disc centre has been in communication with surrounding tissues.* Thus it has also been observed in fenestrated discs.

It is a fact that real regressive changes have taken place in all these cases, that the same processes may be found in a great number of discs which do not show any protrusions and that many discs that seem normal from a macroscopic point of view do show certain microscopic signs of degeneration.

Furthermore, in a majority of cases a direct continuity may be traced between the inner degenerated parts of the disc and the prolapse (Fig. 14). The rupture or ruptures causing the prolapse practically always concern all layers of the a. f. They are radial and most often dorsomedian, in the next place dorsolateral with different aberrations from the median plane. In many cases it is possible to observe even macroscopically how the process has begun with a ventral rupture of the inner layer of the a. f., continued as a circular dissection uni- or bilaterally towards the dorsal side of the disc and finally pierced the outer lamellae on this side (Fig. 18). The dorsomedian ruptures and less often the dorsolateral ones may sometimes extend bilaterally just under the outer lamellae, forming a T-shaped rupture (Fig. 19) and the perforation may then take place straight before the original rupture or beside it. It is not altogether uncommon that the prolapse route need not be straight, and this circumstance is quite frequently found when it is only possible to find the routes histologically by means of serial sections. In these latter cases it is rather narrow and winding (Fig. 20). It is more difficult to reach an exact conception of the localization of the annulus ruptures in relation to the ends of the bodies of the vertebrae. Strikingly often, however, they take place rather near, sometimes immediately adjacent to one of the bodies of the vertebrae (Fig. 20) and in such cases cranial localization is twice more frequent than the caudal one.

The other type of disc protrusions — *type II* — is characterized by considerably smaller size, more limited and regular shape, rather firm consistency and a colour that varies between grey-white and grey-yellow. Prolapses of this type show some very characteristic shapes. They appear either as a rather even diffuse bulge of the dorsal side of the disc, a transversal bulge that is more or less shaped as a threshold (Fig. 21), a median ridge-shaped elevation of the *lig. longitudinale int.* or bud-shaped prominences laterally to this ligament (Fig. 22 and 23). As a rule the prolapses show a smooth and even surface, which adheres to the dura only in very few cases.

The difference between types I and II is further accentuated if we look at the cut surface of the concerned discs. A dystrophic calcification of the n. p. is most frequent in type I, but in type II other degeneration patterns are more usual. In the present material of protrusions of type II only about 25 % have shown a dystrophic calcification of the nucleus and the remaining cases have presented other degenerative changes, either disintegration of the inner parts of the disc or a dull grey-yellow cut surface of the nucleus or in comparatively many cases regressive processes which manifests themselves only when subjected to microscopic examination. The ruptures observed, which are always total in type I, are partial in type II and thus the protrusion against the vertebral canal is formed by a bulging of lamellae and ligaments that have not yet been ruptured. As a rule the ruptures in type II seem to be more winding and narrow. One must often resort to discography (Fig. 24) or serial sections in order to establish the connection between the degeneration focus just under the bulged lamellae and the degeneratively changed centre of the disc. In few cases, however, a connection between the disc centre and the protrusion has not been established. In those discs n. p. may have been even mucoid, thus not showing any visible degenerative changes. The localization of the ruptures seems as a whole to be identical in both types.

As has been shown in the above an obvious morphological difference between two types of protrusion may be found. There are of course occasions when this distinction is difficult to make. It is probable that some of the prolapses of the present material which have been described as belonging to type II may represent either the initial stage or the final phase of a prolapse of type I. This is in fact a matter of course, as the main difference is that one case deals with a total rupture and the other with a partial one. Even if everything points at a rather swift and eruptive process in a prolapse of type I, the morphologist must of course be able to find such a process in being. On the other side one must also allow for the possibility that an old prolapse of type I, bridged by connective tissue may simulate a prolapse of type II. In cases when chronic protrusions of type I adhere firmly to the dura there is no mistaking. The histological examination may give the differential diagnosis in a lot of difficult cases, but nevertheless the possibility remains that some prolapses in the present material may have been erroneously classified as belonging to type II. This is perhaps especially the case in individuals who have shown both types simultaneously. However, this error is not likely to have affected the present conclusions in any degree worth mentioning.

According to *Lindblom* (1951) disc protrusions in man are more often based on a partial annulus rupture than on a total one. The localization and the nature of these protrusions in man have many points in common with the conditions in dog. A subdivision in two types of protrusions, though not so distinct, also appears in human medical literature (*Spurling and Grantham* 1948, *Lewey* 1949, *Lindblom* 1951). 1941 *Lindblom* described dorsolateral ruptures, causing protrusions into the *forr. intervertebralia.* The present dog material does not include cases with disc protrusions situated in these foramina without affecting the epidural space simultaneously.

The meaning of the morphological subdivision in two types of prolapse

As a parallel to this morphological distinction between types I and II we find differences in the symptom picture and the manifestations of the disease as a whole, which confirm the fact that this difference is real and not artificial. If we look at the frequency of the different types of prolapse in connection with age and breed we will find that type I is chiefly found in the chondrodystrophoid breed group and in considerably younger age-groups than does type II. The mean age of cases showing prolapses of type I is 5.78 $\pm$0.36 (n=40, range=3—13). Regarding type II the corresponding figures are 8.77 $\pm$0.32 (n=65, range=4—16). An analysis of variance on these figures gives the following result.

TABLE 10.

Analysis of variance of the age of cases with different kinds of disc protrusions.

Source of variation	Sum of squares	Degrees of freedom	Mean square
Between type I—II	233	1	233
Within type I—II	932	103	9.05
Total	1165	104	

$$\text{Ratio of mean squares: } \frac{233}{9.05} = 26.74^{***}$$

We thus find a highly significant difference between the mean age of cases with prolapses of type I and those with type II prolapses.

Of the 43 cases in the type I prolapse group 39 have belonged to the chondrodystrophoid breed group. The remaining 4 are three spaniels and one "Dachsbrache". This observation will need a special commentary. In american literature (*Riser*, *Schnelle*) spaniel is mentioned among the especially disposed breeds and in Sweden (*Olsson*, personal communication) the spaniel seems, together with the pekinese, to follow next to the dachshund when cases of disc degeneration in the clinic material are concerned. In the present statistics on the frequency of disc degeneration in different breeds which has been presented in chapter IV nothing has confirmed the idea of special disposition in spaniel. However, when disc protrusions are found in spaniel they seem to belong to the same type as that of the chondrodystrophoid breed group and the development of the discs in this breed also shows other similarities to that of the chondrodystrophoid group. It thus seems possible to find a tendency towards disposition for disc degeneration in this breed, though this tendency is rather feebly accentuated at least in this country. One must probably take into account the possibility that a certain fraction, certain families within the breed may be the bearers of an increased disposition for disc disease. The age development of the discs in "Dachsbrache" also suggests a relationship to that of chondrodystrophoid dogs but the frequency of prolapses is remarkably small.

Prolapses of type I are thus found in dogs of the chondrodystrophoid type and in comparatively young dogs. Prolapses of type II, however, seem to be able to affect all breeds and considerably older individuals. In other words they seem to be more or less definitely senile phenomenons.

The clinical course of disc prolapse in the chondrodystrophoid breed types rather often manifests itself as a rather acute disease. Sometimes the animal may not have shown any obvious symptoms to its owner but rather suddenly certain symptoms of disc prolapse appear, often in connection with a trauma, which have even the form of a total paraplegia. Other times the development is not quite as eruptive but the animals nevertheless show rather sudden symptoms of a dorsal insufficiency which change for the worse comparatively soon. It is usual that after reaching a certain maximum the symptoms decrease successively and the animals recover comparatively well. Relapses are frequent after intervals of different length, which may sometimes extend over years. Disc degeneration and prolapse in dogs of other breeds often show a longer course and milder symptoms. The morphological and clinical pictures of the different types of protrusions seem to correspond well to each other.

The general morphology of disc degeneration

The normal age development of the discs

In every one of the cases the disc protrusions of the types described above have been found to be expressions of degenerative changes in the discs. The same experience has been made as regards man. *Friberg and Hirsch* express the matter thus:

"Disc prolapse is a part phenomenon of degeneration of the disc."

Disc degeneration is thus a rather extensive term. Of course quite a number of changes must be counted under this heading which are either stages preceding the ruptures of the annulus and the prolapse of nuclear material or other manifestations. It is well known that from decade to decade the discs in man are subjected to certain changes. These changes have been called regressive and certain difficulties have been met in deciding how much ought to be considered to be within the range of normal physiological processes. *Friberg and Hirsch* are of opinion that

"definite degeneration must be presumed when ruptures are to be observed in the annulus".

It is a matter of course that from a strict general pathologic point of view a degeneration must be considered to exist as soon as regressive changes of the cell nucleus and various forms of disintegration in the cytoplasm and in the intercellular matrix may be found. As disc degeneration is undoubtedly greatly a function of the age of the individual its pathology must also be brought to task in connection with the age changes of the discs.

In the new-born individuals the vertebral column is composed by a number of diaphyses of bodies of vertebrae which are separated from each other by epiphyseal cartilages and discs. The disc is distinctly divided into a. f. and n. p. The latter is formed by a gelatinous limpid mass of tissue which bulges on the cut surface and in most cases is easy to isolate and part from its environment. In this stage no difference is to be found between the different breeds. During the first month a centre of calcification develops in the epiphyses of the bodies of the vertebrae and during the last half of the first year the ossification is completed and the epiphyseal plates disappear. The age changes of the discs seen from a macroscopic point of view are mainly the changes which take place in the n. p. Already during the first half year a significant difference develops between the chondrodystrophoid breed group and other dogs. In the latter group the mucous and gelatinous nature of the n. p. is preserved very long. Only after the age of seven years it is statistically highly significant that the probability to find a fibroid n. p. is greater than that of finding a mucoid one (Table 13). This transmutation of the nucleus develops successively. The strongly gelatinous nucleus of the new-born stage loses its quality of limpidity and almost transparence. It becomes turbid and by and by becomes milk-white, but it preserves its mucoid gelatinous consistency. The continued development is marked by a successive change into a more fibroid tissue of the same type as that of the inner layers of the annulus, which, in uncomplicated cases leads to a homogenization of the cut surface of the disc. Very often, however, the picture is complicated by degenerative processes which will be discussed later on. Side by side with these processes of transmutation a dehydration takes place the size of which will not be discussed in this work. The dehydration results in a reduction in disc length. This reduction does not seem to be greater than is motivated by the mere loss of liquid. It need thus probably not be assumed that resorptive processes of the type described by *Lindblom and Hultquist* are of any significance to the reduction in disc length to which all the discs of the vertebral column are subjected as the animal grows older. But it is obvious that in comparatively advanced ruptures of the annulus they may be made responsible for losses of disc tissue.

In the chondrodystrophoid dogs it is statistically highly significant that the majority of the individuals have lost their mucoid nucleus already in an age of 1 year, this tissue being replaced by a more chondroid one (Table 12). This metamorphosis often begins at the age of 3—4 months and does not show the same successive development as in other breeds. The transition seems to take place rather rapidly and the new nucleus is of a greyish-white or grey-yellow colour and semi-elastic consistency reminding of rather soft caramel. No measurable reduction of disc length has taken place. Macroscopically observable degenerative changes do also appear regularly and early, in the first place calcifications. It is an important question whether the transmutation from mucoid to fibroid or chondroid n. p. is a process which takes place synchronously within the vertebral column or if differences are to be found in different regions of the column. Table 11 shows a statistically highly significance of the fact that the metamorphosis of the different regions does not differ from each other either in chondrodystrophoid or non-chondrodystrophoid dogs.

TABLE 11.

Frequency of mucoid nuclei in different regions of the vertebral column.

		Cervical region	Thoracic region	Lumbar region	χ^2-value [1] (d. f. = 2)
Chondro-dystrophoid dogs	Total number of investigated dogs	206	206	206	
	Number of dogs with mucoid n. p.	39	26	28	3.11
Non-chondro-dystrophoid dogs	Total number of investigated dogs	324	324	324	
	Number of dogs with mucoid n. p.	221	202	216	0.92

The processes described in the above are normal to the two groups of dogs. It is, however, possible to see how some individuals show occasional aberrations towards the development pattern of the other group. As has already been mentioned the disc development in certain spaniels and "Dachsbraches" shows a tendency towards that of the chondrodystrophoid breed group.

Tables 12 and 13 show the metamorphosis of n. p. from the mucoid to the chondroid or fibroid type in different ages in the two breed groups. In the chondrodystrophoid breed group the n. p. is already at the age of 1 year more often chondroid than mucoid and from the age of 4 years the n. p. with few exceptions is chondroid. When other dogs are concerned it is only when the dogs are more than 7 years old that it may be statistically highly significant that the probability to find a fibroid nucleus is greater than 50 %. The χ^2-values show that the chondroid and fibroid n. p:s are not distributed among different ages in the same manner as is the number of investigated dogs.

Macroscopic signs of disc degeneration

The dorsal disc prolapses and the changes in the affected discs have already been described. *The examination has shown that a considerably*

[1] Each χ^2-analysis is a test of the hypothesis that the values in this row are equal.

TABLE 12.

Frequency of mucoid, chondroid and calcified nuclei in chondrodystrophoid dogs of different ages.

Region		< 2 months	2–9 months	1 year	2 years	3 years	4 years	5 years	6 years	7 years	> 7 years	Sum.	χ^2-value[1] (d. f. = 4)
	Total number of investigated dogs	14	39	16	19	23	20	22	15	10	28	206	
Cervical region	Dogs with mucoid n. p. in per cent	100	35.9	25	10.5	13	5	0	0	10	0	18.9	
	» » chondroid n. p. in per cent	0	64.1	75	89.5	87	95	100	100	90	100	81.1	57.42***
	» » calcified discs in per cent	0	20.5	31.2	26.3	26.1	45	50	53.3	70	17.9	31.1	13.81**
Thoracic region	» » mucoid n. p. in per cent	100	20.5	0	0	17.4	0	0	0	0	0	12.6	
	» » chondroid n. p. in per cent	0	79.5	100	100	82.6	100	100	100	100	100	87.4	56.62***
	» » calcified discs in per cent	0	41	62.5	73.7	73.9	80	77.3	100	90	75	65.5	15.66**
Lumbar region	» » mucoid n. p. in per cent	100	23.1	6.2	0	17.4	0	0	0	0	0	13.6	
	» » chondroid n. p. in per cent	0	76.9	93.8	100	82.6	100	100	100	100	100	86.4	55.93***
	» » calcified discs in per cent	0	20.5	43.8	42.1	60.9	70	63.6	66.7	70	50	46.6	33.30***

[1] Each χ^2-analysis is a test of the hypothesis that the values in this row are distributed in the same manner as in the first row ("total number ..."). The absolute, not the relative numbers have of course been used. The number of d. f. is 4 owing to the fact that the columns are put together in pairs.

TABLE 13.

Frequency of mucoid, fibroid and calcified nuclei in non-chondrodystrophoid dogs of different ages.

Region		< 2 months	2–9 months	1 year	2 years	3 years	4 years	5 years	6 years	7 years	> 7 years	Sum.	χ^2-value (d. f. = 9)
	Total number of investigated dogs	16	93	18	27	26	16	18	16	11	83	324	
Cervical region	Dogs with mucoid n. p. in per cent	100	97.8	83.3	85.2	92.3	75	61.1	50	45.5	19.3	68.2	
	» » fibroid n. p. in per cent	0	2.2	16.7	14.8	7.7	25	38.9	50	54.5	80.7	31.8	153.96***
	» » calcified discs in per cent	0	0	5.6	0	4.2	6.3	0	0	0	6	2.5	
Thoracic region	» » mucoid n. p. in per cent	100	96.8	83.3	81.5	84.6	62.5	38.9	31.3	36.4	13.3	62.3	
	» » fibroid n. p. in per cent	0	3.2	16.7	18.5	15.4	37.5	61.1	68.7	63.6	86.7	37.7	168.87***
	» » calcified discs in per cent	0	0	5.6	3.4	4.2	0	5.6	0	18.2	10.8	4.6	
Lumbar region	» » mucoid n. p. in per cent	100	97.8	88.9	81.5	88.5	75	61.1	50	45.5	14.5	66.7	
	» » fibroid n. p. in per cent	0	2.2	11.1	18.5	11.5	25	38.9	50	54.5	85.5	33.3	167.77***
	» » calcified discs in per cent	0	0	5.6	0	0	0	0	0	9.1	6	2.1	

[1] Each χ^2-analysis is a test of the hypothesis that the values in this row are distributed in the same manner as in the first row ("total number ..."). The absolute, not the relative numbers have of course been used. The number of d. f. is 9 and no columns are put together.

greater number of discs have shown signs of degeneration than those affected by protrusions.

In chondrodystrophoid dogs and also in spaniels and "Dachsbraches" a partial or total dystrophic calcification of n. p. is the most usual type of disc degeneration. The distribution within the vertebral column is shown by the curve in Fig. 4. In the present material, in which 232 protruded discs were found, a dystrophic calcification has been observed in 1194 discs. Thus, this degenerative phenomenon which is possible to find even macroscopically has been observed 5 times as often as prolapses. The distribution of these calcified discs along the vertebral column differs from that of prolapsed discs — an observation which repudiates the opinion of *Pommer* (1937) that a roentgenologic demonstration of disc calcification in paraplegia should be decisive of the localization of eventual prolapses. *Olsson* has also disproved *Pommer*'s statement as far as this point is concerned. The frequency of this calcification process is greatest in the thoracic region and decreases towards the ends of the vertebral column. This phenomenon is in accordance with observations of disc calcification in man (*Rathcke* 1932).

TABLE 14.

Frequency of calcified discs in different regions of the vertebral column.

	Cervical region	Thoracic region	Lumbar region	χ^2-value[1] (d. f. = 2)
Total number of investigated dogs	206	206	206	
Number of dogs with calcified discs	64	135	96	25.73***

Table 14 shows that the percent of calcification is not the same in the different regions of the vertebral column. The curve in Fig. 4 especially emphasizes the portion from disc 13 to disc 19. Somewhere in the middle of this portion the point is located that is, according to *Slijper* the most important centre of movement in the vertebral column.

As has already been mentioned the calcification of the discs affects the central parts of the discs. A calcification that is localized to the outer zone of the a. f. is most unusual. The central calcification of the disc affects the n. p. and the inner, perinuclear layer of the a. f. The type and frequency of the localization are shown in the following summary:

Total calcification of n. p. and perinuclear zone of a. f.	925	discs
Partial calcification of n. p. and perinuclear zone of a. f.	262	»
Partial calcification of outer zone of a. f.	7	»
	1194	discs

[1] The χ^2-analysis is a test of the hypothesis that the values in this row are equal.

The partial calcification of n. p. and perinuclear zone of a. f. has of course been subject to variations. However, two types have been distinguishable: one which does not affect the central part of the n. p. and thus shows a calcification formed as an open or closed ring intermediately in the disc (Fig. 26) and the other which shows a calcification in the form of a small nucleus in the centre of the n. p. The former seems to be somewhat more frequent.

It is very usual that the central disc calcification extends through the outer part of the a. f. in the form of pointed or somewhat more rounded extrusions especially in the dorsal direction. They may extend far towards the dorsal side of the disc, as far as to the *lig. longitudinale int.* and in the portion between discs 7 and 14 as far as *lig. conjugale costarum.* In some cases it is only a question of bulges of the lamellae, but most often there are real ruptures of the annulus, which make possible a protrusion of the calcified tissue.

It should be especially observed that the calcification is localized to the central parts of the disc, i. e. n. p. and the inner layers of the a. f. These conditions seem to differ from those in man. Thus *Rathcke* found an overwhelming predominance of the calcification of the annulus, though this view differs from that of *Bársony and Koppenstein* (1930). *Pommer* (1937) had reached the same conclusion as the two latter authors. He stated that in dog a difference existed between an inner zone consisting of n. p. and the inner layers of the a. f., with a tendency towards calcification and the remaining outer zone of the disc, resistent to calcification. In isolated cases, however, he was able to observe a calcification of the outermost lamellae of the a. f. It is, however, probable that the possibility must not be excluded that calcium found in the outer parts is attached to material that has protruded from the disc centre.

In comparison to calcification other forms of degeneration are far more seldom found in these breeds. On the other hand calcified discs are very seldom found in dogs of non-chondrodystrophoid breeds. This fact is clearly shown in tables 12 and 13. As to age distribution of disc injuries it has earlier been shown that prolapses have been observed in chondrodystrophoid dogs already at an age of 3 years and in others at 4 years. This difference is not statistically significant but indicates a tendency. The difference in age between cases of prolapse of type I and those of type II is, however, statistically highly significant. It is clear that disc degeneration is found in considerably younger age-groups among the chondrodystrophoid breeds than is the case among other dogs. Thus calcified discs have been observed in the former in individuals as young as puppies of five months of age and from the age of two years it is statistically highly significant that the probability of finding calcified discs is greater than 50 %. In dogs of the non-chondrodystrophoid type in the present material macroscopical signs of disc degeneration have been found in isolated dogs of an age less than 7 years and even in the age-group above 7 years they do not amount to a considerable figure.

Prolapses or calcifications are easily measurable expressions of a disc degeneration. Other types of degeneration make a certain macroscopic diagnosis more difficult as long as they have not caused any real interruption in the continuity of the tissue. Interruptions in the continuity of the a. f. in the form of ruptures or breakings apart of the lamellae have been mentioned in the above as determinators of the dorsal protrusions. In prolapses of type I this perforation of the a. f. was complete, in type II it was partial. It is of course possible that an examination of a great material of dogs may disclose partial ruptures of the annulus without a protrusion towards the vertebral canal. Many of them are even macroscopically observable, but mostly it is only possible to discover them histologically. They have been especially easy to observe with the naked eye when they have been marked by a protrusion of calcified substance as has been described in the above.

Partial ruptures are very often found in the dorsal part, but more seldom found in the ventral part of a. f. *The annulus degeneration, thus, seems to be more common dorsally than ventrally. The chondroid metamorphosis of the disc centre, however, is not more pronounced dorsally than ventrally. Tillmanns* has maintained that all these processes occur mainly in the dorsal part of the disc.

Furthermore, it is possible to observe, especially in comparatively old dogs of both breed groups, a rather typical change which is located to the dorsomedian part of the a. f. It manifests itself as a homogenization of the usually fibrous structure which becomes more gray than the rest of the a. f. This change may be found in both protruded and unprotruded discs.

On page 54, finally, a certain kind of "brown degeneration" of the centres of ruptured discs is mentioned.

This account of the macroscopic manifestations of disc degeneration would not be complete without some words on *the conditions in the discs of the tail.* In this region no prolapses have been observed. However, signs of disc degeneration have not been missing, though their frequency seems to be very small. In 13 dachshunds of an average of 5 years, all of which did show degenerative changes in the form of calcifications with or without prolapses, only two cases of nucleus calcification (situated in the first coccygeal discs) were found. Chondroid transmutation was, however, found to be synchronic with that of the other discs of the vertebral column. In those cases where a difference in the chondroid metamorphosis has been observed to exist between the cervical region and the rest of the vertebral column the coccygeal discs have shown the same picture as the cervical discs.

Disc degeneration and other diseases in the vertebral column

It is well known from orthopedics that degenerative changes appear in the discs in connection with a number of other diseases than those of immediate interest to this work. This bears upon various changes of shape, especially the *kyphosis*, the intraspongious protrusions and *spondylosis deformans* and allied conditions. Whether or not the disc injuries appearing in connection with these diseases are of a primary nature or not has perhaps not become completely elucidated.

During this study some observations have of course been made in this respect. A number of these might be of interest to the discussion and the author will give a short account of them.

Changes in the shape of the vertebral column

The rôle played by the discs in different forms of *kyphosis* is under discussion. Injuries in the c. p. with intrusion of disc material in the body of the vertebra (intraspongious prolapses) have been regarded as causal precursors of adolescent *kyphosis* (*Donohue*, 1939) and *Kümmell's kyphosis* (*Bradford and Spurling*). *Junghanns* (1931) has also been of the opinion that the senile *kyphosis* is a result of the changes in the discs.

Changes in the shape of the vertebral column in dog is a most rare phenomenon. The author has only found one observation in available literature. *H. Virchow* (1917) described a case of *kyphosis* in dachshund in the thoraco-lumbar transition. *Virchow* stated that in this case the *kyphosis* was an exaggeration of an already existing normal tendency and that it had been caused by muscular action. He did not mention the rôle of the discs in this connection.

During the author's own investigations no cases have been observed in which the shape of the vertebral column has significantly exceeded the normal range of variation.

Intraspongious disc protrusions

These formations, which have been considered significant to the genesis of certain types of *kyphosis* as has been seen from the above, were first observed by *Schmorl* (1926—27). In a very great material he found them in 38 % of the cases. In young and middle-aged material they were considerably more frequent in men than in women. This fact has been regarded as an indication of traumatic etiology. They usually do not seem to be of any clinical importance except in especially serious cases, when they have been considered capable to cause *kyphosis* among other things.

No reliable cases of intraspongious disc prolapses in dog have been described. During the author's own investigations attention has been paid to this problem, and in few cases intraspongious disc prolapses have been observed histologically as subordinate findings. In one case, however, the change was very pronounced and had most probably caused the clinical symptoms of the dog. A short account of this case will be given.

Case history. The dog in question was a 4.5-year old smooth-haired dachshund bitch, which had shown symptoms of a dorsal insufficiency since half a year. She had had difficulties in rising after having lain down, her gait had been very faltering and her back at first slightly, later on more pronouncedly arched and she had been unable to walk in stairs or to leap into chairs. The first consultation resulted in the diagnosis of e. i. and a conservative treatment was applied. The symptoms decreased but did not disappear completely. During some periods the dog's health was comparably good, during others she was severely afflicted by the back disease. The dog went ad mortem because of an intercurrent infectious disease. She had never been x-rayed.

Gross examination (O. 381/50). When the vertebral canal was subjected to section in the usual way no dorsal disc protrusions could be found and neither could any vestiges of eventually healed ones. Thus the spinal cord was macroscopically and histologically free from changes. The discs showed the picture that should be expected in a dachshund of that age. Every n. p. was chondroid and some of those in the thoracic and lumbar regions also showed calcification. Disc 20, differing from the others by a somewhat increased mobility and being abnormally thin, was examined in its sagittal plane and found to have protruded intraspongiously in L 2 following immediately behind. The length of the prolapse was 6 mm and its thickness nearly 4 mm and it thus occupied a considerable portion of the vertebra (Fig. 27). The perforation had evidently taken place rather exactly in the centre of the c. p. and the forward surface of the epiphysis of the vertebral body. The prolapse showed the same tenacious plaster-like consistency as the n. p. and bordered on the spongiosa. The latter did not show any macroscopically discernible changes in the border zone or elsewhere.

Histological examination. This showed that the c. p. and the trabeculae of the epiphysis of the body of the vertebra were turned strongly backwards at the edges of the perforation. The prolapsed n. p. showed the same picture of chondroid metamorphosis and extensive more or less acellular calcified necrosis as was the case in many of the other discs. In the next chapter we are going to discuss this picture more thoroughly. Neither did the histological examination show any obvious reactive change in the spongiosa against the protruding disc material.

As no other essential findings have been made in the back it seems probable that the observed symptoms were derived from this prolapse, probably from the resulting intervertebral instability.

Nothing can be said for sure on the cause of the rupture of the c. p. The anamnesis does not contain any mention of trauma. The axial localization, however, directs suspicions towards the original situation of the *chorda dorsalis* — a *locus minoris resistentiae*, to which *Böhmig*

(1930) among others has directed the attention as far as man is concerned. *Lob*, who has earlier been cited has made an interesting commentary in this connection. He considers that one should not expect intraspongious prolapses in animals, because their epiphyses are fitted between disc and cartilage plate!

Spondylosis deformans and allied conditions

It would be preposterous if a study on disc degeneration in dog, though laying the main stress on the condition connected with e. i., did not touch the problem of *spondylosis deformans*.

In man two main causes of spinal *ankylosis* are taken into account, namely *spondylosis deformans* and *spondylarthritis ancylopoetica* (*Bechterew's disease*). When animals are concerned *Joest* (1926) is of the opinion that the latter disease has not been definitely observed. *Pommer* (1933) and *Schick* (1942) mention *spondylarthritis* in dogs.

In an interesting account of these problems *Junge* (1950) has given a short summary of the modern conception of the connection between disc injuries and *spondylosis*. *Junge* states that when the equilibrium between the mechanical stress and the power of resistance of the tissue is disturbed injuries may result which cause disc tissue to be pressed out into surrounding tissues. In this manner intraspongious and dorsal disc prolapses take place, and also the initial stage of the *spondylosis*. *Junge* says:

> "Nach den ersten Untersuchungen von *Beneke* haben *Schmorl* und sein Schüler *Hammerbeck* (Arch. path. Anat. 1935) die pathologisch-anatomischen Vorgänge in dem Sinne geklärt, dass es ausserordentlich häufig zu Einrissen des vorderen und seitlichen Randleistenannulus kommt, den als Gegenspieler des Innendruckes der Bandscheibe anzusehen ist, zu abrissen am Eintritt in die knöcherne Randleiste und zum Ausweichen des Bandscheibengewebes in diese Lücken hinein. Der nächste Halt ist jetzt das vordere Längsband, das an den Wirbelkörpern ansetzend Randleisten und Bandscheiben überspringt. Durch die abnorme Ausbuchtung des vorderen Längsbandes, die mechanische Zerrung an den Ansatzstellen entstehen die typischen spondylotischen Knochenappositionen, die sich also von der Wirbelkörperecke, der Randleiste absetzen und diese frei lassen. Bedingung ist die weiterbestehende mechanische Beanspruchung und ein gewisser erhaltener Turgor der Bandscheibe, während stärkere Austrocknungserscheinungen, grösserer Elastizitätsverlust und Höhenverminderung sekundär sind und mit der Entstehung der spondylotischen Randwülste nichts zu tun haben".

Schrader, *Lob* and *Junge* have also been able to show experimentally how injuries in the ventral portion of the a. f. may result in changes of the same type as in *spondylosis deformans*. *Junge* also states that *lig. longitudinale ant.* and its intimate connection to the body of the vertebrae and to the periosteum is of decisive importance in this case. That spondylotic changes do not occur in a dorsal direction is explained according to *Junge* by the fact that *lig. longitudinale post.* does not possess this connection but is attached to the disc itself. The same author has furthermore brought together the final result of all these degenerative disc changes in the term *osteochondrosis,* into which is counted changes in the c. p. and *osteosclerosis* in the epiphysis of the bodies of the vertebrae. He thus associated the term used by *Hildebrand* (1933) to design these conditions. *Wissel* (1951) has used the term *osteochondrosis* to designate the chronical degenerative conditions in the discs, which lead to reactive *osteosclerosis* and osteophytes of neighbouring bodies of vertebrae. The nomenclature in this respect, as when disc degeneration as a whole is concerned, does not yet seem to be clearly defined. In the following *spondylosis deformans* will mean the pathologic conditions in the intervertebral spaces which show degenerative changes in the discs, osteophytes with or without *ankylosis* and finally *sclerosis* of the osseous tissue concerned.

Spondylosis deformans in dog has been described among others by *Pommer* (1933), *Ipolyi* (1940), *Schick* (1942), *Fankhauser* (1948) and *Debard* (1949). The comprehensive picture of the disease given by literature is the following. *Spondylosis deformans* is a disease that mainly afflicts old dogs of especially lively breeds (spitz, fox terrier, schnauzer, French bulldog) or working dogs (alsatian, dobberman pincher and hunting dogs). There seems to be no sex dispositions. The disease may sometimes be comparatively local, sometimes general all over the thoracic and lumbar parts of the vertebral column. It is above all characterized by osteophytes of the ventral side of the intervertebral spaces and degenerative changes in the discs. *Pommer* and *Fankhauser* also describe dorsal disc protrusions as part phenomenons in these spondyloses.

Own observations. In the present material of 561 dogs, which has among other things showed 93 cases of dorsal disc prolapses, 49 cases with spondylotic changes have been observed. Of course the selectivity of this material does not provide a sound basis for breed statistics. When dorsal disc prolapses were concerned the dogs could be divided into two main groups, one chondrodystrophoid and one non-chondrodystrophoid breed group. It was also clear that prolapses of type I are almost exclusively found in the former group and that prolapses of type II were found in old individuals from both groups. Of the 49 cases of spondylosis 12 have belonged to the chondrodystrophoid and 37 to the non-chondrodystrophoid group. This is a very probable difference (Table 15).

TABLE 15.

Frequency of spondylosis deformans in different breed-groups.

	Chondro-dystrophoid dogs	Non-chondro-dystrophoid dogs	χ^2-value (d. f. = 1)
Total number of investigated dogs	211	350	
Number of dogs with spondylosis deformans			
Absolute	12	37	4.14* [1]
In per cent	5.7	10.6	

The 12 cases of spondylosis in the chondrodystrophoid group have furthermore been found in individuals which have shown type II prolapses or no prolapses at all. Breeds strongly represented in the spondylosis material were boxer and fox terrier. The distribution between male and female animals in the spondylosis material was 25 and 24 respectively, and the mean age 9.67 ± 0.44 (range 2—16 years, n=45, age data not available in 4 cases). The histogram in Fig. 7 shows how 141 spondylotically changed intervertebral discs from these 49 cases are distributed within the vertebral column. The changes are localized especially to the thoracic and lumbar parts of the vertebral column and show certain maxima. Especially conspicuous is the great frequency in the lumbosacral joint. As is seen the distributions in the vertebral column shows considerable aberrations from that of the dorsal disc protrusions (compare Fig. 4).

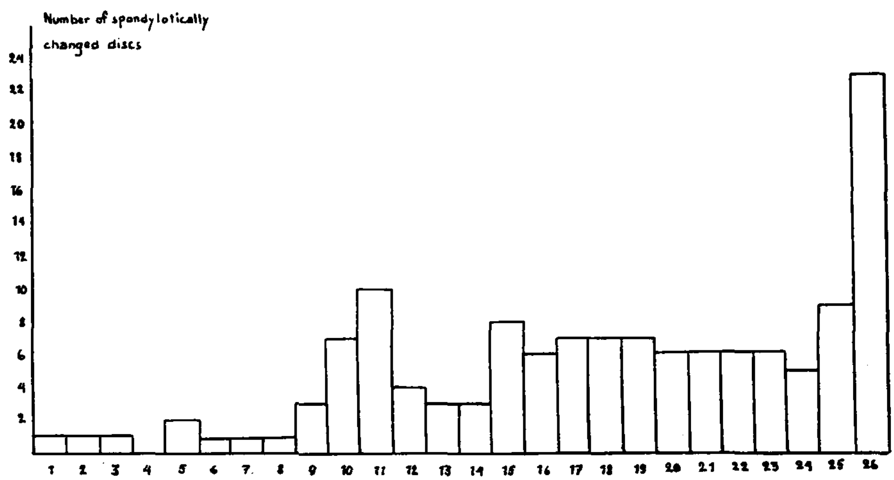

Fig. 7. Distribution of spondylotically changed discs within the vertebral column.

[1] The χ^2-analysis is a test of the hypothesis that the values in this row are distributed in the same manner as the values in the first row.

How the changes in *spondylosis* in dog may look is shown by the picture in Fig. 28. The dog in question is an 11-year old boxer bitch, killed because of a metastasizing thyroidea cancer. The dog also showed what *Pommer* has called a *spondylosis deformans generalisata* which had affected the intervertebral joints from disc 17 as far as the *os sacrum*. Ventrally to the bodies of the vertebrae we find a nearly coherent staff of newly-formed tissue, interrupted on the level of the discs by annulus tissue dislocated more or less strongly in the ventral direction. A. f. in this case shows pronounced decomposition, a grey-brown discolouration and ruptures. The latter are often localized in the immediate vicinity of one or the other epiphysis of the body of the vertebrae. The rest of the disc shows a fibroid transmutation of n. p., though obvious degenerative changes are lacking, and a comparatively intact dorsal portion of the a. f. Finally the picture also shows a *sclerosis* of the part of the epiphyses of the bodies of the vertebrae which is most near to the discs. The *sclerosis* is more accentuated in the ventral portion.

In other cases the disc changes may be much more severe resulting in a decrease of the volume of the intervertebral disc and extensive total decomposition processes and hole formations in the disc. It is, however, a constant phenomenon that the changes in the disc are, as in the above case, most conspicuous in the ventral portion of the a. f. In some cases (illustrated in Fig. 29) a ventral percurrent rupture of a. f. with prolapse of disc material have been assumed to be the probable precursor of a spondylosis deformans. Thus, these cases showed slight osteophytes of the surrounding vertebrae and a fibrous thickening of the *lig. longitudinale ventrale*. These prolapses are strongly reminding of the "äusserlich sichtbare Bandscheibengewebsprolaps" in man described by *Hammerbeck* (1935).

Finally there are cases of *spondylosis deformans* in which the discs show only slight changes. In these cases the process mainly concerns *lig. longitudinale ventr.* and its attachments.

In 18 of the 141 spondylotically changed intervertebral discs also a dorsal disc prolapse of type II was found. 164 such prolapses have been found in the present material. It is thus comparatively seldom that *spondylosis* in this material goes together with a dorsal prolapse of the disc in question (in 12.6 % of the cases) and, vice versa, it is as rare to find *spondylosis* in the concerned intervertebral space in cases of dorsal prolapses (11 %). This observation does not wholly agree with the findings of *Pommer* and *Fankhauser* of an obligate connection between *spondylosis deformans* and prolapses of type II. It is true that both *spondylosis* and type II prolapses are found in the same sort of clientele but not more often in the same disc than has been shown by the above figures.

Table 16 also corroborates the inverse proportion between disc prolapse and *spondylosis*.

Table 16.

Frequency of cases with spondylosis and disc protrusions in dogs of more than 7 years of age.

	Chondrodys-trophoid dogs > 7 years	Non-chondro-dystrophoid dogs > 7 years
Number of dogs with spondylosis deformans	5	14
» » » » disc protrusions	21	6

$\chi^2 = 11.88^{***}$ (d. f. = 1)

In short it thus seems that the dorsal disc prolapses of type I, those of type II and spondylosis deformans are three morphological expressions of disc degeneration that are rather well demarcated from each other. It is furthermore clear that the type of disc development and disc degeneration that finally results in disc prolapses of type I is incompatible with spondylosis deformans, while the type of disc degeneration which results in prolapses of type II has certain points in common with the spondylosis deformans.

Chapter VI

THE HISTO-PATHOLOGICAL BACKGROUND OF THE GENESIS OF DISC PROLAPSES

Introduction

The macroscopic examination has shown that the dorsal disc prolapses are a part phenomenon in a considerably more extensive disc degeneration. The possibility has also been indicated by this examination that these degenerative processes are dependent of the age development of the discs. For this reason the histological examination has been made with the intention to follow this disc development. First a description will be given of the disc during the new-born stage of the animal and then of the age changes in the non-chondrodystrophoid breed group, which shows the type of disc development most frequent in dog. Finally an account will be given of the histology of the discs of the chondrodystrophoid dogs.

As the nomenclature of the histology of the supporting tissues is not clearly defined an acount will be given of the terms chosen by the author. Both the cellular pathology of *Virchow* and the "syncytial doctrine" of *Hansen* and *Häggquist* place the cells and the endoplasm areas respectively in the centre of the vital processes of the tissue. The endeavour by *Hansen* (1905) and *Häggquist* (1929) to conceive all intercellular substance as a part of the cell by means of the term exoplasm has, however, seldom been mentioned in modern research. This does not mean that the connection between the cells and the formed and unformed components of the intercellular substance has been explained (*Klemperer*, 1950). *Wilton* (1937) and *Sylvén* (1945) have chosen to speak of cells and intercellular substance or matrix. Without deciding this problem and in spite of the difficulties in finding the cell boundaries in the concerned tissues the author has followed the example of *Sylvén*. Thus the cytoplasm is mainly identical to the endoplasm of *Hansen* and *Häggquist* and the intercellular substance or matrix is the structure located between these cells. *Sylvén, Paulsson, Hirsch and Snellman* (1951) have found when studying the ultrastructure of n. p. that the homogeneous part of the intercellular substance observed by means of usual microscopic technique was also composed of fibres.

Material and methods

As is known from the above the macroscopic examination had been performed in two different ways. The histological preparations have mainly been taken from the material which had been examined by means of method 1. The sections consequently include the whole of the disc. Also from the sagitally sectioned material a number of discs have been subjected to a histological examination in organic connection with the bodies of the vertebrae. This material has been decalcified according to Perényi.

The following fixation fluids have been used: 10 % aqueous solution of formaldehyde, *Helly*'s fluid, 9 % aqueous solution of mercuric chloride, *Allen*'s modification of *Bouin*'s fluid, *Carnoy*'s fluid, 4 % aqueous solution of basic lead acetate (*Holmgren and Vilander* 1937), and saturated picric acid in 10 % formaldehyde solution to which certain sulphates have been added (*Crétin* 1924). This fixation fluid has little decalcifying effect on account of its added ingredients of easily dissolvable sulphates. For the examination of the amount of glycogen the specimens have been fixed in a mixture of 2/3 absolute alcohol and 1/3 formalin. (For this part of the investigation the disc specimens were removed immediately after the dog had been killed.)

The following three staining methods have been used by routine: hemalum-eosin, hematoxylin-picric acid fuchsin (*van Gieson*) and *Heidenhains* azan stain. Moreover the following special stains have been used: Scarlet red, *Weigert*'s elastic tissue stain, hemalum-eosin according to *Bock* together with *Crétin*'s gallic acid-formol method (1924) for calcium, *Best* carmine stain for glycogen together with *Lillie*'s modification of *Bauer-Feulgen* stain, *Weigert*'s fibrin stain together with *Ladewig*'s modification of *Mallory*'s anilin blue collagen stain, *Hueck*'s modification of *Tiermann-Schmelzers* Turnbull's blue method for iron, *Palmgren*'s silver staining method (1948) for nerve fibres, toluidine blue according to *Sylvén* (1941) or saturated thionin solution for "chromotrope substance", silver nitrate impregnation according to *Foot and Foot* for argentophilic fibres and finally *Lepehne*'s benzidine test for haemoglobin.

The histology of the disc in the new-born stage and the early puppy stage

In the new-born puppy where the bodies of the vertebrae are ossified only in the diaphysis vertebra and disc are not morphologically clearly demarcated. The cartilage of the epiphysis of the body of the vertebra has its proliferation zone towards the diaphysis and otherwise presents the picture of a resting cartilage. Towards the intervertebral space which is mainly marked by n. p. the cells of this resting cartilage become more flattened and extended in length. On a sagittal cut these oval and long cartilaginous cells are seen immediately adjoining to n. p. As is seen from Fig. 30 it is sometimes possible to find a funnel-shaped retraction of this border line. The direction on the cells follows this deviation with a linear prolongation axially through the cartilage of the epiphysis with condensation of the intercellular substance. It does not seem to be excluded that this phenomenon indicates the foetal location of *chorda dorsalis*. Dorsally and ventrally to n. p. the intervertebral space is bridged by the same cells which are now extended in length in the cranio-caudal direction. In the same place it is also possible to see how the cells of the resting cartilage change their shape successively and the intercellular fibres change their direction. Though this portion, this bridge between the two epiphyses has a tendency to look like fibro-cartilage it is however clear that it is still obviously part of the epiphysis. Apart from the n. p. counting from the outside the intervertebral tissue in this stage consists of an outer lamellar connective tissue, rich in collagen and sparse in cells and next, the above-mentioned cartilaginous bridge between the epiphyses. The outer half of this latter tissue contains more intercellular substance and less cells than the inner perinuclear part. Moreover, the outer part has a definitely lamellar pattern. The cells of the perinuclear region also differ from those of the outer one. They are more difficult to demarcate from surrounding matrix and their nucleus is bigger, rounder and more light-coloured. The intercellular substance of a. f. has a metachromatic tingibility decreasing towards the periphery of the disc. The lamellae of the outer layer of a. f. show a fish-bone pattern and are kept together by a loose less fuchsinophilic tissue. This interlamellar tissue is furthermore metachromatic, while the lamellae proper are markedly ortochromatic. The ventral and lateral lamellae but not the dorsal ones behave tinctorially more or less like tendinous tissue. *Van Gieson* gives a colour-scale from red to yellow, *Heidenhain*'s azan stain and *Ladewig* give blue to red. The more towards the periphery, the more homogenized and yellow the lamellar tissue becomes with *van Gieson* and red with the two other methods. The outer part of a. f. also shows a rather rich vascularization. The proportion between these different layers in a. f. of the newborn puppy differs somewhat in chondrodystrophoid and non-chondrodystrophoid dogs. In the former the loose perinuclear layer occupies a considerable space while it may even be lacking in the non-chondrodystrophoid dogs (Figs. 31 and 32). In the latter the transition from the perinuclear layer of a. f. to n. p. is more distinct than in the discs of chondrodystrophoid dogs. It is thus possible to observe a gradual decrease in tissue differentiation from the outside towards the centre analogous to that described in man by *Prader*. Furthermore the low-differentiated components occupy a greater part of the picture in the chondrodystrophoid than in the non-chondrodystrophoid group.

N. p. in its turn is a syncytium of rather typical cells. These cells do not look uniform but vary especially depending on the size, shape and chromatinic density of the nuclei. Many transitionary forms exist, between cells whose nuclei reminds of those of fibrocytes, i. e. thin, hyperchromatic and rather small and cells with a comparatively big round and light-coloured nucleus. The cytoplasm may often be strongly vesicular and the intercellular substance forms a homogeneous basophilic substance divided by thin slightly fuchsinophilic fibres (Fig. 34). The cytoplasm may contain small amounts of Scarlet-positive structures and as a rule it contains a rather high proportion of glycogen. The basophilic matrix reacts positively to Feulgen after having been oxidized by means of periodic acid and shows a rather pronounced metachromasia with toluidine blue and thionin. Silverimpregnation as a rule gives a negative result. *As a whole one may say that in this stage the n. p. does not seem to be a degenerated tissue.* It is not possible to find any regressive changes in the nuclei with certainty. Furthermore, to judge from this comparably rough picture there is no reason to consider that the cells of which the nucleus is composed are of different kinds. On the contrary it seems reasonable to presume that they represent the same cell in different degrees of maturity.

Another example from the animal kingdom will be given, which clearly illustrates the vital character of the n. p. and the uniformity of the cell picture. The animal in question is the guinea pig. According to the author's own observations, of which an account is given in Fig. 33, it is possible to find in both new-born and adult animals a uniform n. p. rich in cells.

Concerning man it has been supposed by means of among other things electrophoretic studies that the intercellular substance of n. p. most likely contains chondroitin sulphuric acid (*Sylvén*, 1951). Among others *Compere and Keyes* (1933) and *Prader* maintain that n. p. is a vital structure contrary to the opinion of older investigators (*Virchow*, 1857 and others). Furthermore *Coventry, Ghormley and Kernohan* (1945) have designated the cells of the nucleus of the new-born individual as "notochordal remnants", meaning the type of cells designated as physaliform by *Virchow*. In the adult individual, however, these authors found two types of cells, i.e. fibroblasts and cartilaginous cells. *Eckert and Decker* (1947) considered that n. p. always contained three different types of cells, viz. fibroblasts, cartilaginous cells and true chorda cells. *Hass* (1942) found that the n. p.-cells as well as the a. f.-cells reacted positively to a stain, specific to cartilage cells.

What has been said above of the discs of the new-born dog also applies to the whole of the early puppy age, i. e. the suckling period. No substantial changes in the discs are found in the author's material up to the age of two months.

According to the author's observations the disc of the new-born dog shows three histological components. In the centre the low-differentiated n. p., next an inner layer of a. f. the character of which is fibro-cartilage and whose perinuclear layer shows a lower degree of maturity than the more peripheral one and finally the outer highly differentiated lamellar portion of the a. f. In chondrodystrophoid dogs the lower *degree of maturity of the perinuclear layer is more conspicuous than in non-chondrodystrophoid ones.*

The age changes of the disc in the non-chondrodystrophoid breed group

The fibroid metamorphosis

As has already been pointed out in the preceding chapter n. p. long preserves its mucoid character in these breeds of dogs. It is only during real old age that the continuous aging process has gone so far that the n. p. has become comparatively fibroid. How does this metamorphosis look in the microscope?

2—9 months of age. In this age group the discs have very little diverged from the primary stage outlined above. In some cases the picture is wholly identical. In others a small decrease of the metachromasia of the intercellular substance is observed together with a parallel increase in its fuchsinophilic properties. The cells do not show any changes worth mentioning, the nuclear picture is normal and the proportion of glycogen in the cytoplasm is approximately the same as before. The increased fuchsinophilia of the tissue tends to lobulate the n. p. and in the periphery, where n. p. and perinuclear layer of a. f. merge into each other such lobuli may show signs of both progression and regression. The latter manifests itself as necrobiotic nuclear changes, especially karyolysis and pyknosis and the occurrence in and around the cell groups of rather characteristic scales. These scales are acidophilic and with *van Gieson* seem to show affinity to the picric acid. They often are banana-shaped (Fig. 44). A certain tendency to progression may also be observed in the form of cell division pictures, and newly-formed young cells with great karyoplasmic ratio. This also applies to as well the cells of the n. p. proper as those of the perinuclear layer. These divergencies from the picture of the primary stage are, however, insignificant details and the prevalent impression is that no considerable changes have taken place.

1—7 years of age. In this age group it had been possible to observe macroscopically a continuous dehydration and clouding of n. p. from the original limpid gelatinous appearance to a greyish or milky white, though the mucoid character of the n. p. was preserved in most cases.

Microscopically, the picture is characterized by a continuous decrease in the metachromatic property of the intercellular substance parallelled by an increase in its fuchsinophilia. This phenomenon which we may call collagenization is often localized to the portion of the intercellular substance which is next to the cytoplasm, and to the intercellular plasma bridges on which the syncytial disposition of the tissue is based. The collagenization either takes place uniformly and diffusely over the whole of the n. p. or tend to divide the organ into lobuli. The former process (Fig. 35) seems to be the most uncomplicated one and takes place without conspicuous degenerative changes of the cells. They are changed thus that their nuclei decrease in magnitude and become hyperchromatic. The cytoplasm is also changed. It becomes smaller and thus the nucleus approaches the surrounding fuchsinophilic structure. The vesicular character remains however, but the vacuoles are smaller. No considerable change of the glycogen proportion of the cells seems to take place during this process, which gives the impression of being a slow maturation. In this process the perinuclear layer has remained passive.

On the other hand this layer seems to take part in the other type of collagenization, in which n. p. is divided into lobuli. At least the process begins in the periphery of n. p. with the separation of small parts of n. p. from the rest. They become surrounded by a slightly fibrous fuchsinophilic substance which continues into the perinuclear layer directly. Those parts of n. p. which become isolated in this way may either degenerate in the same characteristic manner that has been described in connection with the preceding age-group, or in the same way show signs of a slight progression. But it is especially the cells of the perinuclear layer that show these signs of progression.

Ages over 7. In the above age-group small degenerative foci were frequently found in n. p. When it comes to ages which represent old age in dog the frequency of degenerated discs will be very high. It is however possible to find discs in which even the histological picture will lack degenerative characteristics to a great extent. The n. p. of these discs then shows a picture that seems to be the final stage of the above-mentioned maturation (Fig. 36). The cells of the n. p. are found in a net of fibrillar collagenic bundles. Their original character is still discernible in that of the cytoplasm, which has now rather small vacuoles. The nucleus is comparatively small, hyperchromatic and often oval-shaped. In the meshes of the net a certain content of "chromotrope substance" may still be observed and the proportion of glycogen in the cells does not seem to differ significantly from that in younger discs.

Further degenerative processes

N. p. + the perinuclear layer of the a. f. The fibroid metamorphosis of n. p. has been conceived in the above as a continuously progressing maturation and not as the result of a degeneration, though it has been pointed out that degenerative processes are a usual component in the picture during this development.

The further degenerative processes are more diffusely spread over n. p. and perinuclear a. f. portion. The degeneration is characterized by cellular changes sometimes with pyknosis, sometimes with karyolysis, and by changes in the collagenized intercellular substance. The latter loses its fuchsinophilia and often shows the earlier mentioned scales with affinity to the picric acid of the *van Gieson* stain. It is by and by transmuted into an amorphous finely granulated mass. The changes of the cell are dominated by the nuclear changes. It is true, however, that the vacuolar structure of the cytoplasm is eraded and its content of glycogen disappears. No increase or decrease in Scarlet-positive drops seems to take place. In one case a great number of fine Scarlet-positive drops with a colour scale from bright red to a dirty yellow have been observed. The disintegration of the cells is often complete and in that case big or small foci show the picture of a pure necrosis without any cellular components. This necrosis does not show any conspicuous affinity to any one of the stains used. It is thus, e. g. fibrin-negative and non-argentophilic. In rare cases it may however be the site of calcification.

When degenerative processes appear in younger ages they are usually local and situated in the zone where the perinuclear layer of a. f. and the n. p. merge into each other and accompanied by a progressive activity of cells. This faculty of new formation of cells is obviously attached to the perinuclear layer of a. f. It is characterized by a sometimes rather brisk proliferation of cells, which gather themselves in big or small groups in the same manner as in cartilage. In the small groups the nuclei are often disposed in a wheel-spoke pattern. These groups of cells are separated from each other by an intercellular substance, rich in collagen especially close to these groups. This chondroid tissue which may sometimes be observed in these dogs and then usually in foci is a very important component in the development of the disc in the chondrodystrophoid dogs and will be discussed later on.

A. f. The outer part of the a. f. consists as has earlier been mentioned of the fish-bone patterned structure of lamellae, which are joint by a looser substance. Degenerative changes may be located to both these components. They more often seem to affect the interlamellar tissue together with a loosening of the connection between the lamellae. In this connection we find a granular substance stained beige or dirty-brown by *van Gieson*. It is calcified in some exceptional cases. Big or small foci of the same appearance may also be observed in the lamellae proper. Those latter also may show the picture of a hyaline degeneration with a swelling of the collagen, homogenization and fragmentation of the structure and rather intensive fuchsinophilic tingibility. Such changes usually are the background of the characteristic, macroscopically observable change dorsomedially in a. f., which was described on page 65.

When do these changes appear and which is their connection with degenerative changes in n. p.? It was obvious already macroscopically that discs with a seemingly normal n. p. might be the seat of type II protrusions. Histological investigation sometimes reveals foci of degeneration in a. f. before n. p. has been subject to any comprehensive changes. This circumstance represents an important difference between the genesis of disc degeneration in these dogs and in the chondrodystrophoid ones. Instances have however also been found of the fact that degenerative changes may appear simultaneously in the centre and periphery of the disc and that the degeneration of the nucleus may come first.

Annulus ruptures and the dorsal protrusions

As has already been seen from the above a disintegration of the connection between the lamellae of the a. f. may occur. In the histological preparation this often looks like isolated phenomenons. In different places big or small foci of indifferent granular mass may be seen between or within the lamellae, seemingly with no connection to each other. These foci often form a linear passage between the centre and periphery of the discs. In serial sections it is possible to follow such processes and observe that they represent a narrow, winding and probably ramified communication between the inner and outer parts of the disc. These degenerative foci are very similar to the degenerated inner parts of the disc, a similarity that becomes more pronounced when cellular components are included in the picture. This breaking of the lamellae seems to be the most usual type of rupture. Cross ruptures of the lamellae proper may however often be observed in the sections, though a great number of them are artefacts. In intravital ruptures the ruptured ends of the lamellae are often rounded, club-shaped and hyalinized.

It is thus possible to show, in great number of discs, microscopic signs of a disturbance in the continuity within the a. f. with something which might be called "intradiscal protrusions". They are seen both in the dorsal and the lateral directions. As a rule, however, the ventral processes are stopped by the resistance of the outer part of a. f. which differs from the dorsal annulus in being very strong and tendinous. Sometimes the degenerative process may be traced as far as to the ventral longitudinal ligament, even with prolapse and possibly combined with osteophytes. The histology of the spondylosis will not be subjected to further discussion in this work.

The dorsal degenerative processes, however, often reach further towards the periphery and by and by they cause dorsal protrusions of type II. The outer portion of these prolapses consists of bulged lamellae or only the bulged longitudinal ligament (Fig. 56). These structures may show the picture of hyaline degeneration with swelling up and fragmentation. Under them the granular, eventually calcified necrosis is seen, which can in many cases be shown to have communication with the inner of the disc through separations and ruptures of the lamellae. In some cases such a connection has not been wholly established. An intermediate layer of unbroken lamellae has then remained between the peripheral degeneration focus and the degenerated or normal n. p. However, the possibility of a rupture in the immediate vicinity of the vertebra next ahead can not be excluded. That such ruptures exist may be seen from sagittal sections. Another possibility is that the continuity is unbroken but the protrusion is caused by a bulging of the whole of the degenerated and weakened portion of a. f., which has thus yielded to the pressure of an n. p. that is comparatively uninjured from a functional point of view.

Summary

In dogs of the non-chondrodystrophoid type the age development of the disc is characterized by a successive collagenization of n. p., which in this connection is regarded as a maturation process. This maturation is often disturbed by degenerative changes both in n. p. and a. f. Separations and ruptures in the dorsal a. f. may result in "intradiscal protrusion" of material from the centre with a bulging of the outer part of a. f. (protrusion of type II).

The age changes of the disc in the chondrodystrophoid breed group

The chondroid metamorphosis

In the chondrodystrophoid dogs it is statistically highly significant that already most of the 1-year old individuals have lost their mucoid nucleus and had its place taken by a more chondroid tissue. We will now follow this process microscopically.

2—9 months of age. Already in the beginning of this period it is possible to find signs of a metamorphosis of n. p. with the changes above all localized to the region where the perinuclear layer of a. f. and the n. p. merge into each other. This perinuclear layer, which in these dogs is low-differentiated fibro-cartilage, is composed by cells that usually lie together two and two in rows and sometimes are disposed in round groups of cells with four or some more cells. The intercellular substance shows a metachromatic tingibility and is passed through by fuchsinophilic fibres. The transition into n. p. is diffuse. In this perinuclear layer signs of a cellular activity soon appear. Cell division pictures appear of probably both mitotic and amitotic character (Fig. 41—43). Other cells give an impression of being young and newly-formed with high karyoplasmic ratio and a light-coloured, round or irregularly shaped nucleus. Comparatively big groups of cells of the above-mentioned circular shape begin to appear in greater quantity and often contain a great number of cells. The nuclei are often placed in a wheel-spoke pattern in each of these groups of cells, but in groups where the cells are more numerous a more irregular pattern is found. In these groups of cells the intercellular substance is metachromatic and only contains small amounts of fuchsinophilic substance. By and by, however, the amount of collagen increases and half-moon-shaped cells as a rule dispose themselves in twos in the same way as in ordinary cartilage. The accumulation in big round cell groups remains, however, and between these groups we find small areas of non-cellular, fibrous and fuchsinophilic character in a background of metachromatically tingible matrix. Simultaneously to this cellular activity in the perinuclear layer of a. f. considerable changes take place in the peripheral portions of the n. p. In them we find a successively increased proportion of fuchsinophilic substance, which is however not diffusely distributed but tends to divide the nucleus into big and small lobuli. These "interlobular" fuchsinophilic passages as a rule show a direct continuity to the perinuclear layer of a. f. and thus contribute to make the border between these two portions of tissue a diffuse one. In this way n. p. will be successively divided into such lobuli, in which the original character of the tissue is still preserved in the beginning (Fig. 37—40). By and by these lobuli may however change, either in the form of a degeneration or in a manner that preserves the vital character of the tissue. In the latter case these lobuli show a very great number of cells of a comparably immature type with light-coloured round nucleus and high karyoplasmic ratio together with detached cell division pictures. Thus, such a small isolated part of n. p. may show a picture that is nearly completely identical to that of the above-mentioned groups of cells in the perinuclear layer of a. f. It is a matter of course that it is not possible to know with certainty in such cases from which tissue such a group of cells originates. To judge from transition forms in the border zone the possibility of such a transformation of nuclear tissue into chondroid tissue of the same character as in the perinuclear layer seems however to be probable. Degenerative processes in the n. p. lobuli are also seen, characterized by disintegration of cells with karyolysis and pyknosis and a granular disintegration of the intercellular substance into a substance that is indifferent to the stains used by the author.

This chondroid metamorphosis, which seems thus to begin in the periphery of the nucleus, has in certain cases gone so far that the whole n. p. is changed into such a tissue. In this case n. p. may show a homogeneous uniform picture, which is characterized by the described chondroid cell groups, separated from each other by broader passages of collagen embedded in metachromatic matrix. In other cases the peripheral primarily changed portion may have changed its character: the number of cells has been reduced and the big groups of cells have disappeared. In the centre, however, the cellular activity may imprint the picture — in this place we now find the interaction between cellular progression and degeneration of nuclear substance.

It seems to be more usual, however, that before the central portion has accomplished its metamorphosis more or less extensive degenerative changes sometimes with secondary calcification have already appeared in the chondroid peripheral portion. It is true that the chondroid metamorphosis of the n. p. is connected with degenerative processes in this organ but the resulting chondroid tissue is a vital structure during the early stage of its existence. This process proceeds very rapidly in the chondrodystrophoid dogs. It corresponds to the fibroid metamorphosis of n. p. in other dogs but its course is considerably accelerated and also shows great differences in principle. The secondary degenerative processes already mentioned characterize the further aging of the disc in these dogs while the faculty of cellular activity in the tissue has not yet vanished.

Further degenerative processes

N. p.+the perinuclear layer of a. f. In many representatives of the age-group of 2—9 months and in the majority of the younger members of the next age-group (1—7 years) it is possible to observe more or less extensive degenerative changes in the chondroid peripheral portion of n. p. In the centre of n. p., however, the chondroid metamorphosis continues contemporaneously with a degeneration of eventually remaining nuclear material and of the newly-formed chondroid substance. Already macroscopically it was very often possible to observe a difference between the peripheral and central portions of n. p. The calcification could be found in the centre of n. p. or, which was much more common, peripherally. Furthermore it was usual that the n. p. of these discs which were not calcified had a central rather yellowish portion and a grey-white periphery. As has been mentioned before a difference between the centre and periphery of n. p. has been possible to observe also microscopically. The picture is richly varied but nevertheless seems to follow some principal lines which will be outlined in the following.

The place in the disc in which it shows a diffuse transition between a. f and n. p. in young animals and where the chondroid metamorphosis begins shows a decrease in the number of cells in the more advanced cases. However, the proportion of cells increases towards the centre of n. p. In this connection the centre shows a cellular activity of the same nature as has been observed peripherally during the earlier stages. Thus the peripheral part of n. p. gives the impression of having been replaced by the perinuclear layer of a. f. This also seems to be the case, even if some of the cell components probably consist of n. p. cells changed to a more chondroid type of cells. This seemingly broadened inner layer of a. f. constantly shows signs of degeneration, varying from single small foci with disintegration of especially the intercellular substance to a total and regularly calcified necrosis of the whole peripheral portion of n. p. The central chondroid portion in these cases is surrounded on all sides by a "mout" of necrotic and calcified material.

The local regressive processes most usually manifest themselves as a diffuse grainy disintegration of the intercellular substance which loses both its metachromasia and its fuchsinophilia and forms a granular mass that is indifferent towards the stains used by the author. In some cases this granular transmutation seems to have been preceded by a fibrolysis with generation of argentophilic but Weigert-negative fibres. In this degeneration mass the cells by and by succumb either in a diffuse disintegration with karyolysis or otherwise they preserve their shape for a long time surrounded by a thin, highly fuchsinophilic membrane and showing pyknosis. Often such remains of cells are found, completely isolated and bathing in an otherwise non-structural calcified necrosis. In single cases this grainy decomposition may show hyaline characteristics and strong fuchsinophilia and in others affinity to the picric acid of the *van Gieson* stain.

Finally the decomposition manifests itself in one more form, which has already been mentioned several times and which seems to be characteristic of disc degeneration as a whole (Fig. 44). It manifests itself as the appearance in the intercellular substance within or in the immediate vicinity of the cell groups of irregular, often banana-shaped scales of the approximate size of a cell nucleus. These scales are acidophilic and conspicuously "picrinophilic" with *van Gieson*. They are accompanied by degenerative nucleus changes, especially karyolysis and pyknosis in the concerned groups of cells. The cytoplasm often shows a disintegration with tinctorial resemblance to these scales. In certain cases real foci of densely placed "picrinophilic" scales may be observed, but they never reach the same great extension as does the granular necrosis. Instead their size corresponds more to that of the chondroid cell-groups.

The central chondroid remaining part of the nucleus shows a wholly different degeneration picture. In it we often find a cellular activity, characterized by groups of cells tightly clustered together and very rich in cells, which show an immature picture with high karyoplasmic ratio and signs of division. As a rule the intercellular substance is more fuchsinophilic than that of the peripheral chondroid tissue. The degenerative changes are in this case characterized by a disintegration of the intercellular substance into big intensively fuchsinophilic hyaline fragments, brought together into rather big, irregularly shaped foci. Less often than in the periphery the degeneration is acompanied by a calcification. When this is the case the calcification is always scaly and thus differs from that of the periphery, which is homogeneous or finely grained.

This division into periphery and centre of the different manifestations of the nucleus degeneration is typical. Nevertheless cases are found in which nucleus shows a veritable helter-skelter of these different pictures. Both in periphery and centre we then find alternatingly foci of still vital cellular pattern and foci of the degeneration types described above. Furthermore the whole central portion of the disc may be the seat of degeneration with total lack of vital cell components. In such cases the picture may be very uniform, as the whole n. p. consists of a homogeneous or granular and calcified, almost completely acellular necrosis.

The processes in the intercellular substance are characterized by a disappearance of the basophilia of the tissue and the appearing structure may either show a certain affinity to the picric acid in the *van Gieson* stain or be hyalinized or totally indifferent. The degenerative foci do not show a fibrin-positive character either in Weigert-stained or in Ladewig-stained sections and do not show argentophilia. Furthermore the foci are orthochromatic towards toluidine blue and thionin.

The calcification of the degenerated intercellular substance in the majority of the cases, except from those mentioned above, is of a homogeneous, non-structural or granular character. That the necrosis does really contain calcium has been chemically ascertained. The salts are mainly phosphates and also carbonates. It reacts positively on *Bock's* hemalum. With the gallic acid formol method of *Crétin* a blue lac forms quickly which we has not been able to preserve on the sections in spite of observing all the precautions prescribed in the original work. Also on *Bock* the reaction is feeble even if *Crétin*'s prescription of adding easily dissolvable sulphates is followed in the fixation. When discs are stained by means of *Palmgren*'s silver impregnation method the calcified necrosis shows a strong, finely granulated blackening. According to a personal communication *Palmgren* has had the same experiences concerning calcium but considered that it was not possible to exclude that the granular structure of the precipitation was an artefact. With this method, however, the extension and localization of the calcium has been easy to observe. It shows that the calcium has its main seat in degenerated parts of the intercellular substance between the cell groups. As the cell groups and the intercellular substance within them degenerate and disintegrate these portions also show calcification. Finally the calcified necrosis may form a homogeneous acellular structure or show single cells or cell groups that have not yet succumbed entirely.

The cellular degeneration may have taken place as a diffuse disintegration of the cell with karyolysis or pyknosis. At other times the cell has become isolated from its vicinity by a comparatively dense collagen membrane and its nucleus has been pyknotic. Only in isolated case an increase in the proportion of lipids in the cell has been found.

Tillmanns observed vacuolar enlargement and fatty degeneration of the cells in all his cases. *Norlén* (1927), *Brack* (1929) and others observed fatty degeneration of disc material in man.

A. f. Degenerative changes in the outer lamellar portion of a. f. have never been observed without comparatively comprehensive changes in the central portions of the disc being found. These processes do not differ in principle from that of non-chondrodystrophoid dogs. They thus affect the intercellular tissue which disintegrates and also the lamellae themselves with similar disintegration processes or with hyalinization. This disintegration may appear as a fibrolysis with the genesis of argentophilic fibres (Fig. 47) or as a granular transmutation of the intercellular substance into an indifferent granular mass. The process is more often found in the inner layers of a. f. than in the whole of this portion and in such cases it is possible to see the bulging of degenerated lamellae, which give an impression of having yielded to the pressure from the necrobiotic central part of the disc (Fig. 48). Such lamellar bulges are very common in the dorsal and rare in the ventral direction.

The hyalinization most often affects the outer stronger lamellae and often also *lig. longitudinale int.* Then these structures are swollen, homogenized, highly fuchsinophilic and more or less strongly disintegrated into fragments.

Annulus ruptures and the dorsal protrusions

It is a matter of course that small disturbances of continuity appear very soon in connection with degenerative changes in the a. f. Ruptures or small breaks in the lamellae are found. It has often been testified in literature that the preparation of the section, which is very difficult from the technical point of view, results in a lot of artefacts. Of course many of the observed interruptions in the continuity have resulted from the section. Therefore they must be estimated with caution and one must insist upon obvious degenerative phenomenons in their vicinity in order to mark them down as intravital. An additional difficulty in reaching an estimate is the fact that the presence of degenerative changes may increase the tendency towards artificial ruptures. It is possible for an experienced technician to make excellent sections from an intact disc. Thus the existence of ruptures in a. f., even artificial ones, may as a rule be conceived as an indication of the existence of degenerative changes.

Definitely intravital are also those ruptures in which the resulting fissure is filled with degenerative material from the inner portion of the disc. These processes, which have already been designated as "intradiscal protrusions" have been observed in all degrees. The abovementioned dorsal bulges of degenerated lamellae have often been accompanied by ruptures in those lamellae. In other cases a somewhat more diffuse granular disintegration of the inner layer of a. f. has prepared the way for the nucleus, this often happens in the dorsal direction but may also be observed in other directions. Furthermore, it is sometimes possible to observe a small cross rupture of the inner lamellae with a narrow pointed protrusion of nucleus (Fig. 49). Between these nuclear protrusions, which are the smallest of all, and the total ruptures of a. f. with big prolapses all degrees exist. It is usual that such a small rupture is accompanied by a dissecting protrusion of nuclear material in the interlamellar tissue. The prolapse route then becomes winding because the lamellar ruptures may be localized to different parts of the disc. Thus even an inner ventral rupture of a. f. may cause a dorsal protrusion. Most often the prolapse takes a rather broad linear route through a. f.

The ruptures of a. f. in these dogs are considerably more comprehensive than those of the non-chondrodystrophoid group. Whether the rupture has pierced the a. f. completely or not it thus shows a strongly disturbed continuity in a smaller or bigger sector. We find ruptured lamellae which are fibrolytically or granularly disintegrated or hyalinized alternatingly with necrotic material from the disc centre. The hyalinized lamellae are sometimes club-shaped, sometimes split at the edges of the ruptures and they are often rolled up. Finally it is also possible to find many cases in which the inner ruptured lamellae deviate and protrude together with the nuclear material through a rupture in the adjoining peripheral lamellae.

The picture of the protruded material varies with the duration of the process, i. e. the time that has passed since the rupture took place. The disease as such is of course always chronical when it has resulted in a rupture. Thus the histological picture of the prolapse may show an acute, a subacute and a chronical type.

The acute prolapse is mainly characterized by two components, the protruded material and an haemorrhage (Fig. 50). The prolapsed material as a rule is of the same nature as the n. p. and the perinuclear layer of a. f. in a very advanced stage of degeneration. It may however show single small cell groups of a still rather vital character even showing division pictures and cells of an immature pattern. However, they form av very modest part of the protrusion. In most cases the protruded material is dominated by the acellular necrosis, which is most often calcified.

The epidural haemorrhage that accompanies the prolapse is as a rule rather important in size and in certain cases its volume is approximately the same as that of the prolapse proper. The haemorrhage is localized to the periphery and also infiltrates the protruded material. Sometimes the haemorrhage may also be combined with leukocytic extravasation.

The subacute prolapse has added a third component to the picture in the form of a well-developed inflammatory reaction (Fig. 51). This granulation tissue develops everywhere between the tumultuous fragments of the prolapses and by and by pervades them too. Big fragments of degenerated disc material may thus be divided into smaller ones. As a rule it is richly vascularized and for the rest consists of polymorphonuclear leukocytes, fibroblasts, large mononuclear cellular components and very often of polynuclear giant cells. It contains a slightly fuchsinophilic intercellular substance in which sometimes argentophilic fibres are also found. The big mononuclear cells and the polynuclear giant cells seem to be most frequent at the edges of degenerated and calcified material. In specimens stained according to *Bock* or *Palmgren* such cells have been shown to contain calcium grains in their cytoplasm. It seems probable that these cells possess the faculty of phagocytosis and that the inflammatory component is the manifestation of a foreign body reaction. *Lindblom and Hultquist* have observed a similar reaction with great faculty of absorption, though no foreign-body giant cells were found. The polynuclear giant cells of the author's material contain up to about ten nuclei and the form of the cells is very irregular. In some cases the nuclei are dislocated towards one side of the cell. In one case such giant cells have been found in direct continuity with capillary endothelium which indicates the possibility that they may originate from the latter (Fig. 51). Furthermore the big mononuclear cells are often siderous, especially in the periphery of the prolapse and in the vicinity of still remaining haemorrhages.

Except the abovementioned consequences of the agression of the granulation tissue the prolapsed material shows approximately the same picture as that of the acute prolapse. In this case, too, minor signs of cellular activity may be found in the chondroid tissue.

The chronical prolapse is exemplified in the casuistics of the following chapter, cases II and III. As a rule its volume is smaller and it is often characterized by a chronical fibrous adhesion between a small-nodular dorsal surface of the disc and the dura. In this chronical granulation tissue we find necrobiotic and calcified remains of prolapsed disc material, which is strongly surrounded by connective tissue (Fig. 53). The cells are fibroblasts and large mononuclear cell components. On the scene of the original perforation of *lig. longitudinale int.* we usually find the club-shaped and hyalinized edges of the rupture and in the rupture proper a plug of granulation tissue projecting downwards to some extent and in which the mononuclear cell components are especially frequent (Fig. 54). The picture is identical to that of man, found by *Lindblom and Hultquist* and observed by *Olsson* after fenestration of the disc.

Chronical prolapses very often are combined with a dirty-brown and somewhat greenish discoloured disintegration of the disc. Histologically, such a disc is characterized by a helter-skelter of degenerated and ruptured material and big hollows. In these hollows we sometimes find a more or less abundant number of partly agglutinated red blood-corpuscles. In other cases such a disc may be vascularized. It is either a question of comparatively small capillaries or simply a covering of the big hollows in the inner portion of the disc consisting of an endothelium-like membrane and a more or less abundant number of red blood-corpuscles in the hollows. Staining according to *Hueck* of such discs does not indicate any presence of iron. On unstained sections the reaction of *Gmelin* is negative. By means of *Lepehne*'s benzidine test, however, benzidine-positive structures may be found both in cases with intradiscal haemorrhage and in such cases where no signs of an haemorrhage are found by means of conventional staining methods. The structures are very small, varying in size from somewhat smaller than a red blood-corpuscle down to a finely disintegrated powder. Such small grains may be found in big or small heaps in the intercellular substance (Fig. 46). Sections from discs without discolouration, for additional security taken from same dog from which discoloured ones have been taken do not show those benzidine-positive grains.

Summary

In dogs of the chondrodystrophoid type the age development of the disc is characterized by an early initiated, very accelerated transmutation of its central portion into a tissue of a more chondroid nature. This metamorphosis takes place with signs of both progression and regression of n. p. cells and the cells of the perinuclear layer of a. f. To this picture further degenerative changes of the n. p. and of the whole a. f. are soon added. Among them the dystrophic calcification plays an important part. As a result of comprehensive disturbances of the continuity of the a. f. material from the inner portion of the disc may by and by force its way mainly in the dorsal direction. Total ruptures give protrusions of type I. The protrusions are acute, subacute or chronical. As a rule they are accompanied by big haemorrhages and an extensive inflammation, which is most often of the foreign body reaction type with mononuclear and polynuclear phagocytic cell elements. The prolapses may diminish in volume through a reabsorbing activity from this granulation tissue and through reduction of the inflammatory reaction. An increase in volume may occur on account of a secondary rupture of a prolapse bridged by connective tissue (Case III, chapter VII). The small signs of a cellular progression observed are probably of secondary importance in this connection.

Discussion of the histological picture

The age changes of the disc in the non-chondrodystrophoid dogs have been described as a fibroid metamorphosis, as the process is characterized by collagenization and the cells become more and more fibrocyte-like. The character of the process is that of a slow maturation, while, in chondrodystrophoid dogs the corresponding process occurs during very early stages and with great rapidity. The resulting tissue is, from a rough histological viewpoint, of a more cartilaginous character. This is the case with the shape and disposition of the cells and the character of the intercellular substance with a large amount of collagen fibres on a metachromatic background. Both processes show vital cell elements in the portions in which this process takes place. According to *Klemperer* the presence of normal cell elements is as a rule necessary to the genesis of collagen fibres. *Sylvén, Paulsson, Hirsch and Snellman* point out that the fuchsinophilia of n. p. becomes more prominent in the disc during aging and in areas subjected to "degeneration". The citation marks indicate that the authors have doubted that it is really a degenerative process that takes place. The high proportion of cells and intercellular substance in the chondrodystrophoid dogs indicates that the collagenization is more the result of cellular activity than the expression of a degeneration.

The chondroid metamorphosis takes place simultaneously to degenerative changes. The cellular activity seems to continue until no vestiges remain of the original n. p. tissue. In this and later stages the faculty of cellular progression, though not completely vanished, seems to have become less important. *According to the author's interpretation of the sections the progressive tendencies which have been attributed to this disease in all literature, have taken place in the disc before the disease has resulted in rupture of a. f. and prolapse.* Similar opinions have been expressed by *Tillmanns* though he has only examined prolapsed discs, and concerning man by *Saunders and Inman.*

Concerning the particulars in the pictures of the degenerative process proper some have been of special interest. The processes in the intercellular substance have been fibrolysis, though without pictures of a "fibrinoid" degeneration, hyalinization and various kinds of granular or scaly disintegration, in which the tissue has by an by become indifferent to the methods of staining used by the author. The degeneration has always been characterized by a marked disappearing of the metachromasia of the tissue. *Sylvén et al.* also mention that the higher the degree of degeneration (no citation marks) the smaller the proportion of metachromatic material in the n. p. will be.

In some discs with a total rupture of a. f. a special type of degeneration has been found which shows *a brownish discolouration,* which with the common staining methods does not show any special tinctorial properties. *That this type of degeneration is always found in total ruptures and in some cases shows haemorrhage or vascularization seems however to justify the suspicion that in spite of the lack of iron reaction the discolouration may be of a haemoglobinogenic origin. This is also indicated by the fact that benzidine-positive structures are found in discs showing this kind of discolouration.*

The "brown degeneration" has often been described in man. *Brack* (1929), *Saunders and Inman* (1940) have assumed that it is caused by haemorrhage. *Beadle* (1931), *Schmorl and Junghanns* (1932) and *Joplin* (1935) suspect some unknown pigment, which has probably no connection with the haemoglobine.

The calcification of the disc in dog has been regarded as a dystrophic phenomenon throughout the author's material. The same applies to the conditions in man. *Schmorl and Junghanns* consider, however, that a general disturbance of calcium metabolism ought to be taken into consideration in this connection. (See chapter VIII).

Finally, the author's observations of the prolapses proper seem to agree with the conception of their dynamics that has been generally accepted since the rejection of the tumour theory. *The prolapses do not show any important progressive processes. The reason for their changes in volume is to be found elsewhere.*

Chapter VII

CASUISTICS ILLUSTRATING THE CONNECTION BETWEEN CERTAIN CLINICAL SYMPTOMS AND THE PATHO-ANATOMICAL PICTURE IN DISC PROTRUSION

The cases of disc protrusion accounted for in this work represent three different categories,

1) dogs who have died or been sacrificed on acount of this disease,
2) dogs put to post mortem from other reasons, but supplied with anamnestic informations of back trouble and
3) dogs without anamnestic informations of symptoms indicating the existence of disc protrusions.

It is difficult from several reasons to get a real idea about the frequency of *disc protrusions causing no clinical symptoms.* Of 561 investigated dogs 93 have had disc protrusions and data on clinical symptoms have not been given for 27 of these. We must, however, remember that the material is selected — dogs with symptoms of back disorders have of course been overrepresented. For that reason 27 may be too small a figure. On the other side some of these dogs may have had symptoms which have not been recorded. The latter alternative may partly be due to the fact that the symptoms have been of a merely subjective nature.

The cause of death of dogs suffering from disc protrusion has mostly been euthanasia owing to a poor prognosis. In some cases, however, the dogs have died from septicaemia or uraemia, due to infections in the urinary tracts. Finally disc protrusions may cause the dogs to die from "spinal shock". In these cases there are always very pronounced subarachnoid haemorrhages and a severe break-down of the spinal cord substance, connected with haemorrhages. The protrusions in these cases have always been of type I, showing signs of an explosive course. *Olsson* has directed our attention to these cases showing a characteristic myelogram. *Mc Grath* also reports acute lethal cases of disc protrusion without mentioning anything about the cause of death. This is not the place to discuss this interesting neuro-pathological phenomenon. However *acute paraplegia with "spinal shock", caused by a disc protrusion* will be exemplified.

Case I. Black smooth-haired dachshund, ♂, 6 years old.

Case history. For a year the dog has at times been unwilling to move. A few days before it was taken to the clinic the dog had begun to show tenderness of the belly and arched back. Later it had difficulties in crawling up from its basket or in walking up and down stairs. On arrival at the clinic the dog showed rather pronounced ataxia and arched back. When being strapped to the table for roentgen examination it cried out with pain and afterwards showed total paraplegia and a state of severe shock. The dog is sitting with its neck stiff, with staring look and trembles all over. When the dog walks its step is mincing. Examination of sensibility and reflexes is difficult owing to this state of shock. Hyperesthesia exists in the hind quarters and the belly is rigid. Myelography shows a total block of the subarachnoid space at disc 18. The dog was sacrificed two days after this accident. During the interval it had severe pains, cried at night and in the daytime often was lying apathetic or sitting, its back strongly arched and the hind legs streched forward. Also priapism supervened. The dog was sacrificed *in agone*, showing subnormal temperature.

Gross examination. (O. 824/50). *Post mortem* was performed immediately after death. The lungs showed a moderate emphysema. The mucous membrane of the intestines was highly hyperaemic. A slight rectal coprostasis existed. The spleen was highly enlarged (relative weight 1.64 %) evidently due to an increased amount of blood. The liver also was big and rich in blood (relative weight 3.46 %) with slight subserous edema in the gall bladder. The urinary bladder was dilated by 200 ml urine somewhat mixed with blood and grounds. Its mucous membrane also showed an inflammation picture. The prostate was slightly hypertrophic.

Examination of the spinal canal showed the following. On disc 18 there was to the left of the *lig. longitudinale int.* a rather firm prolapse measuring 6 × 3 × 3 mm,[1] grey-yellow, calcified and bridged by connective tissue. It was partly broken through and a secondary protrusion, soft and grey-red, extended in the cranial direction on the left side of the vertebra. In front of and to some extent behind it spread subarachnoid haemorrhages were seen. These were spread as far as to the axis. The spinal cord substance itself showed spread haemorrhagic infiltrates. This prolapse was the only one in the spinal canal. Except from discs 2, 16, 17 and 18 the other showed a chondroid n. p. with somewhat protruding homogeneous yellow-white cut surface. The mentioned excepted discs showed a total calcification of the disc centre. Regarding disc 18 nucleus was evacuated through a dorsolateral annulus rupture, which communicated with the above described primary protrusion.

Histological examination. The liver is the site of a moderate, the spleen of a marked congestion of blood and the urinary bladder shows the picture of an acute haemorrhagic cystitis. The brain and the meninges show a very pronounced hyperaemia. Examinations of sections from the cervical and thoracic parts of the spinal cord shows marked subarachnoid haemorrhagic infiltrates and also considerable haemorrhages in the spinal cord combined with pronounced malacia. Finally there is blood effusion also to the central canal.

[1] length × width × height.

Sections from a number of discs of the cervical, thoracic and lumbar region show a more or less marked degeneration of the disc centre. The degenerated parts often are acellular and granular with a structure stained dirty-brown with van Gieson. Alternating with these foci there are parts with still vital, even proliferating cells and other parts show initial necrobiotic changes with the characteristic "picrinophilic" fragments. The necrotic parts are to a large extent calcified. Finally there are also degenerative changes in a. f., above all in the interlamellar tissue with the lamellae separated away from each other or partially ruptured.

In disc 18 nucleus is evacuated. The transitional zone between n. p. and a. f. shows remaining parts of the acellular calcified necrosis. A dorsolateral cross rupture of a. f. joins the evacuated disc centre to the primary protrusion observed macroscopically. The tissue of this part of the a. f. is very confused with a chaos of ruptured and retracted lamellae separated from each other by the same necrotic material as could be observed in n. p. Any cellular activity does not exist. The dorsal face of the protrusion is perforated and the necrotic material gets lost in dorsal direction. Whether this is the intravital secondary rupture or an artefact can not be determined. Peripherically the primary protrusion, however, has been bridged by a chronic inflammatory tissue, still rich in cells, but also rich in collagen fibres.

Protrusions of type I are characterized not only by a more acute course but also by a tendency to self-healing and to relapses. As has earlier been mentioned several *pictures pointing to a processe of healing* have been observed in the present material. This will be exemplified.

Case II. Brown smooth-haired dachshund, ♂, 9 years old.

Case history. The dog was found dead in a fox-burrow 3 days after having disappeared during hunting. When the dog was 3.5 years old it had suffered from a rather pronounced posterior paralysis, preceded by a period of dorsal insufficiency. It was treated conservatively with good result and rather soon after that the dog was used in hard hunting. A short time afterwards, however, it got two relapses with an interval of a few months. After the age of 4 years the dog had had no symptoms from its back in spite of the fact that it had been used in very hard hunting.

Gross examination. (O. 274/50). *Post mortem* revealed that the dog had died from myocardial degeneration. The autopsy findings will not be described except for the discs.

After the vertebral arches had been taken off and the spinal cord was to be removed a strongly fibrous and very firm adhesion between the dura and the discs 18, 19 and 20 was observed. The adhesion concerned practically the whole dorsal face of the discs and could not be disengaged. For that reason the dura was left in these places. The size of the protrusion between disc and dura was difficult to determine in each single case. The protrusion from disc 20 seemed to be the biggest one with a size of about 9 × 5 × 5 mm. Most of the prolapse was situated laterally and possibly interested the nerve. It was greyish-white and firm, possibly osseous. Examination of the discs showed total calcification of the disc centres in the thoracolumbar region, including discs 18—20. The remaining discs showed partial calcification and a chondroid n. p. Some of the thoracic discs exhibited partial ruptures of the dorsal annulus with "intradiscal protrusion" of calcified material towards the *lig. longitudi-*

nale costarum. Between the calcified disc centre and the dorsal protrusion there was in discs 18—20 a linear narrow communication, filled with a greyish-white partly calcified mass. Between disc and dura in this three cases a firm greyish-white tissue was seen.

Histological examination. Sections from the cervical and thoracic discs show a chondroid n. p. in various stages of degeneration. In some of them there are local necrobiotic changes with the formation of "picrinophilic" granules and scales in and around the chondroid cell-groups combined with pyknotic and karyolytic changes in these. In other discs the necrobiotic changes concern the perinuclear layer of a. f. and the disc centre more or less entirely with only a few small groups of still vital cells. In these discs necrobiotic changes are seen also peripherally, sometimes with a loosening of the interlamellar tissue, sometimes with the lamellae separated away from each other or partially ruptured and thus with the existence of "intradiscal protrusions". Discs 18—20 show such spread changes of n. p. and the perinuclear layer of a. f. with a total rupture of a. f. dorsally. The protruded disc material is stopped by a barrier, consisting of chronic granulation tissue from the epidural space. The granulation tissue is rather rich in cells and vessels and joins the dorsal face of the disc to the fibrously thickened dura. The cells in this granulation tissue are fibroblasts, large mononuclear cells, lymphocytes and plasma cells. It shows isolated foci of calcified disc material together with solitary centres of chondroid tissue with degenerated cell groups. The intercellular substance shows a diffuse transition to that of the surrounding connective tissue almost indicating an anaplastic processe. Regarding disc 20 such a chondroid nodule is the site of ossification.

Olsson has discussed the reasons why relapses do occur. He showed that they could be explained not only by later occurrence of a protrusion at some other disc but also by increase in size of an existing protrusion. In the present material there are reasons speaking in favour of both possibilities. The attacks of the disease most often are fewer than the number of protrusions, observed at *post mortem.* In 10 cases, however, the observed protrusions have been fewer than the number of announced attacks of the disease. *Olsson* presumes the existence of a dynamic factor, playing a rôle in causing and supporting the *symptoms.* In the present material there is a case, pointing to the possibility that *a protrusion may occur by degrees.*

Case III. Black smooth-haired dachshund, ♂, 5 years old.

Case history. About 1 year before its arrival at the clinic the dog had got a dorsal insufficiency and had hardly been able to walk. Paraplegia, however, did not occur. After having suffered from these symptoms for about half a year, the dog was all right again. After an additional half-year's period of health the dog, however, got a relapse. At the clinic it exhibited a stiff and strongly arched back and the left hind leg was paralysed. The dog could still make use of his right hind leg. As to the rest hyperesthesia existed with a diffuse transition cranially to normal sensibility. Myelography: total block of the subarachnoid space at disc 19. The dog was sacrificed at the owner's request.

Gross examination. (O. 96/50). Except the changes in the spine and minor subordinate findings the *post mortem* showed nothing but a rather pronounced dilatation of the urinary bladder. The urine, however, was apparently normal.

Examination of the spinal canal showed two disc protrusions — one at disc 15 measuring 11 × 5 × 3 mm. It was situated in the median plane as a plateau-shaped elevation with a greyish-yellow rather smooth surface and a soft granular consistency. It was highest just over the disc, successively sloping towards the edges, especially in caudal direction. No adhesion to the dura and no apparent spinal cord compression. The other protrusion situated at disc 19 in the median plane and measuring 5 × 5 × 5 mm was almost globular. It had a fixed fibrous adhesion to the dura and the spinal cord showed a corresponding impression. In other respects this protrusion was similar to the first mentioned one. As to the rest all the discs showed a chondroid more or less degenerated n. p. The disc centre was calcified in its major part in the following discs: 5, 6, 11, 12, 15, 16, 18, 19, 22—25. The discs 15 and 19 were narrower than the surrounding discs in addition to the above mentioned protrusions. The macroscopical section did not reveal any continuity between disc centre and disc protrusions.

Histological examination. Sections from cervical and thoracic discs show a constant characteristic picture. The centre of the chondroid n. p. exhibits a hyaline degeneration. The intercellular substance in this region is fallen into homogeneous various pieces showing very marked fuchsinophilia. The cells show degenerative changes, but may also be rather unaltered. In the periphery of n. p. and in the perinuclear layer of a. f. the picture is different. Here we have a more or less advanced necrosis with acellular, granular foci or with foci showing the characteristic picrinophilic scales in and around the cell groups.

Disc 15, examined in serial sections shows centrally in n. p. a degenerated, partly calcified chondroid tissue, rich in cells. Peripherally in n. p. and in the perinuclear layer of a. f. an acellular, granular, calcified mass is seen forming a "mout" round the disc centre. This "mout" of degenerated material protrudes through a rupture of a. f. forming a dorsomedian bulge of the strongly thickened and hyaline *lig. longitudinale int.* Above this bulge a mass of the same nature as the necrotic n. p. is seen. In the first 15 cranial sections of the series these two components of the protrusion are separated from each other by a partly ruptured ligament (the following sections show an unbroken ligament). The fact that the ruptures of the ligament is seen only in the first sections point to the possibility that the definite breaking through has occurred close to the vertebra in front of the disc. Disc 19 especially concerned in this case shows a n. p. strongly changed as to size and shape. N. p. is very small, pear-shaped with its base ventrally. It is strongly degenerated with disintegration and loss of the fuchsinophilia of its collagen and spread degenerated nuclear changes. The processe can be traced in dorso-median direction, but is stopped by some intact lamellae. In the continuation some degeneration foci of various size are seen in and between the lamellae, being on a line between the dorsomedian point of n. p. and the protrusion. The latter is formed by calcified necrotic material of about the same nature as that of n. p. *Lig. longitudinale int.* strongly hyaline and fallen to fragmentary pieces is broken through with a club-shaped thickening. On the dorsal side of the ligament a bud-shaped protrusion is seen, broken because of an artefact in its dorsal surface. The protrusion forms a unitary room, though it shows a pronounced tendency towards a division into one ventral and one dorsal part. These two parts are separated from each other by means of bridges of connective tissue, projecting from the wall, but leaving a rather broad communication between the two parts. These bridges of connective tissue may probably have formed an unbroken bridge over the ventral part, secondarily ruptured and thus pointing to the possibility that the protrusion may have occurred by degrees (Fig. 55). After examination by means of serial sections a connection between the disc centre and the protrusion could be established.

Protrusions of type II most often occur without showing obvious symptoms or with a chronic lingering disease picture. Next case will demonstrate this matter.

Case IV. Alsatian, ♀, 9 years old.

Case history. The dog had died after having suffered from an acute disease, characterized by gastrointestinal disturbances, weakness of the heart and dyspnea. The owner, called up in the telephone, told that the dog had always shown great vitality which had, however, been reduced during the last year. It had shown irritation towards its play-fellow, it had been lying in its basket for longer times and had left this place unwillingly and cumbrously. Thus, the owner had observed decreased vitality but no obvious signs of back trouble.

Gross examination. (O. 624/50). The *post mortem* revealed as most important findings an acute gastro-enteritis, blood congestion in the liver and the spleen, hyperaemia and edema in the lungs together with subendocardial and subepicardial haemorrhages.

Examination of the spine showed a ridge-shaped median elevation of the *lig. longitudinale int.* at disc 19 measuring 5 × 1 × 1/2 mm. It was greyish-white with rather firm consistency and even surface. No adhesion to the dura or any obvious spinal cord compression. At disc 23 there was a similar protrusion, measuring 9 × 3 × 1 mm and to the right of this a bud-shaped, protrusion, measuring 3 × 3 × 1 mm. At disc 24 there was a median ridge-shaped protrusion, measuring 9 × 3 × 3 mm and showing a corresponding spinal cord compression without adhesion to the dura. The discs in general showed a fibroid n. p. In the thoracic region and backwards this fibroid nature was more pronounced and the colour had a certain yellowish tinge. On the cut surface of the discs 19, 23 and 24 the connection between the disc centre and the protrusions was visible macroscopically.

Histological examination. Section from one of the thoracic discs shows an entirely fibroid n. p. with signs of degeneration within foci of various size. The intercellular substance in these foci has lost its fuchsinophilia and its fibrillar structure. Instead it is granular and "picrinophilic". The cells often are entirely destroyed, some times a pyknotic nucleus still remains. Degenerative foci of the same nature can also be traced in the dorsal part of a. f. The lamellae in this part of a. f. are not marked so distinctly as in normal discs. They are instead swollen with a homogeneous somewhat hyaline impress. Disc 19 shows a diffuse necrosis of n. p. with a granular break-down of the intercellular substance and cell destruction, often with a remaining pyknotic nucleus. In the investigated section no connection between the disc centre and the protrusion was seen (such a connection had however been established macroscopically). The protrusion presents itself as a median bulge of the *lig. longitudinale int.*, which is very thin in this place. Under this bulged part of the ligament protruded degenerated annulus material is seen. The prolapse is due to ruptures of the immediately underlying lamellae. These are swollen, homogeneous with still rather pronounced fuchsinophilia and are separated from each other by a granular interlamellar mass. Throughout the dorsal part of a. f. there are degenerative foci. The protrusion is completely free from reaction in that the epidural tissue lacks the faintest sign of inflammation.

In one third of the cases with clinical symptoms these have been slight and diffuse, e. g. back pain, stiffness or weakness of the hind quarters and ataxia. Such cases sometimes may show surprisingly severe changes. The protrusion may even be larger than in cases with more serious symptoms. This discrepancy between clinical symptoms and *post mortem* picture has often been testified in the literature (*Tillmanns*, *Fankhauser*, *Olsson* among others).

The remaining two thirds of the cases with clinical symptoms have shown signs of paralysis — paraplegia in 86 cases and monoplegia in 3 cases. This preponderance of the paraplegia may probably be explained by the morphological fact that the protrusions have occurred more often through dorsomedian than through dorsolateral annulus ruptures. A mere nerve root compression is moreover very seldom to be found. As is well known median disc protrusions injure the spinal cord more severely than the others. *Stookey* (1940) has demonstrated this fact in a paper dealing with cervical disc prolapses.

The localization of a protrusion is furthermore of importance to the symptomatology of the disease, in as much as *the cervical disc prolapses* show a different clinical picture than that of the thoracolumbar ones. This will be exemplified.

Case V. "Dachsbrache", ♂, 7 years old.

Case history. The dog was admitted to the surgical clinic with the anamnesis that it since three days had difficulties walking downstairs. On the level ground, however, the dog had shown no such trouble, but had kept its back very arched. The day of admission to the clinic the dogs condition had grown worse. Status on arrival: The dog was apathetic. It would not lie down, but was standing up with its head stretching forward. The neck was very stiff and the back was arched. There was a slight tonic cramp in the hind legs and the tail. Further, the dogs gait was very stiff. There were, however, almost normal movements of the right front leg, but in the left one there seems to be a paresis of mainly the muscles supplied by the *nervus radialis*. Reflexes seemed to be normal and skin hyperalgesia could be clearly established. The dog moaned however when one tried to bend its neck. Ordinary roentgenogram of the spine showed concerning the cervical portion a narrowing of the spaces between C3 and C4 and between C5 and C6. The thickness of this disc seemed to be half the normal. Furthermore disc 3 was calcified. Myelography gave the following result: The contrast medium shows a small protrusion of disc 2 and stops just cranially to disc 3. As the owner did not want to have the dog treated neither surgically nor conservatively it was killed after the myelographic examination.

The dog should not have been subjected to any violent trauma. It has, however, always strived in its lead and often rushed forward in full speed when bound, which has brought the dog to stop abruptly.

Gross examination. (O. 77/51). Except for the findings in the spinal canal a local chronic myocarditis, a chronic infarction of the kidneys and a hypertrophy of the prostate were the most important changes observed.

In the vertebral canal on the left side along the whole C5 there was a fairly soft, dark red-greyish formation, the width of about 3 mm. There was a corresponding compression of the spinal cord. This protrusion thus lying along C5 was connected with disc 3 as well as with disc 4. Disc 3 showed a diffuse bulge of a height of 2—3 mm and on its highest point there was a rough area with a somewhat granular coating, connected with the above described big protrusion. Disc 4, however, showed the greatest changes with a total cross rupture in its caudal part. The rupture is as broad as the spinal canal. On a sagittal section through this part of the cervical region it was revealed, that this annulus rupture reached into n. p. and was situated close to C6, i. e. the vertebra behind the disc. The edges of the rupture and the n. p. were the site of a pronounced haemorrhagic imbibition. The disc was collapsed. The same sagittal section, also included disc 5, which showed a rupture of the upper part of the dorsal annulus without prolapse of nuclear material. Disc 2 showed a rupture of the inner layer of a. f. with a slight dorsal bulge of the disc. The remaining discs showed alternatingly a pure chondroid n. p. and a calcified one. In the latter case n. p. was often pear-shaped due to a dorsomedian rupture of the inner annulus layer with "intradiscal" protrusion of the calcified necrosis.

Histological examination. Disc 3 shows a necrotic and calcified n. p. with isolated foci, still exhibiting cellular pattern. It loses itself dorsally through an artificial total rupture of the a. f. The inner parts of the ventral a. f. is the site of isolated interlamellar foci, showing the same picture as the central necrosis.

Section from the large cervical protrusion (the epidural formation along C5) shows two main parts, one strongly degenerated nuclear material with isolated foci still exhibiting cellular pattern and the other a marked haemorrhage. The haemorrhage occupies in this section approximately as big a space as does the protruded material. The section from disc 20 shows marked degenerative changes in the centre. Within this area all stages from still rather vital chondroid tissue to completely acellular, granular necrosis are represented. However, nothing is seen indicating a breaking through of the annular tissue.

Case I shows that a violence may be able to release severe symptoms directly when disc degeneration is present. The problem about the rôle of violence in the disc prolapse genesis is under discussion and will be touched upon in the next chapter. A case of *so-called traumatic disc prolapse will be exemplified.* This diagnosis will apply to such cases in which a single extreme violence has ruptured a disc that is not remarkably degenerated. Thus, they remind of the case in man, described by *Middleton and Teacher* (1911).

Case VI. Mongrel, ♀, 9 years old.

Case history. The day before the dog was admitted to the clinic it was run over by a car. After that it had moved very slowly and cautiously until it got a total paraplegia some hours later together with difficulties in urination and defecation. Ordinary roentgen examination revealed a strongly compressed disc between L 4 and L 5, The dog's condition did not improve during the two days it stayed at the clinic. In view of the unsatisfactory prognosis the dog was sacrificed at the owner's request.

Gross examination. (O. 1/50). Except the changes in the spinal canal the dog had a pronounced coprostasis in its colon and rectum.

On disc 23 there was a 3—4 mm high dark-red gelatinous and fibrinous epidural coating, which was highest at the level of the disc and covered the vertebrae in front of and behind the disc. The disc in question was completely destroyed with protrusion of the n. p. bilaterally to the *lig. longitudinale int.* and showed marked disintegration of the whole a. f. There was a corresponding compression of the spinal cord. The other discs showed a fibroid n. p. and only two of them had visible degenerative changes in the form of calcification.

Histological examination. Sections from the cervical discs show a nucleus, sparse in collagen fibres. It is the site of moderate degeneration, strictly limited to the nucleus. A. f. is completely free from signs of degeneration. The disc protrusion is formed half by degenerated nuclear material, half by haemorrhage and some acute inflammatory cell infiltrates.

Summary

This chapter illustrates in casuistic form the connection between certain clinical phenomenons and the morphological picture.

Case I shows a disc prolapse of type I with acute course and mors from spinal shock.

Case II shows pictures pointing to a processe of healing of a prolapse of type I.

Case III shows a picture pointing to the possibility that a protrusion may occur by degrees. The dog had had relapses.

Case IV shows a disc prolapse of type II with very slight clinical symptoms.

Case V shows the characteristic clinical entity, produced by a cervical disc protrusion. In this part it is also discussed why paraplegia is more common than monoplegia in thoracolumbar disc protrusion.

Case VI finally exemplifies so-called traumatic disc protrusion.

Chapter VIII

GENERAL DISCUSSION

The object of this work is shown by its title. Its subject is the disc degeneration in dog and this term has been defined as a comprehensive denomination of all states in which regressive changes may be found in discs. Fig. 8 presents an outline of the author's conception of the term disc degeneration, based on the observations described in this work. Degenerative changes may be localized to n. p. and the perinuclear layer of a. f. on one hand and to a. f. on the other. In the majority of the cases degenerative changes are first found in the central portions of the disc. When the chondrodystrophoid dogs are concerned the order n. p.—a. f. seems to be an absolute rule. The centrifugal quality of disc degeneration has been marked by an arrow. The changes in the central portions of the disc consist on one hand of the chondroid or fibroid metamorphosis of n. p., on the other of different kinds of further degenerative changes. In this case an arrow is also used to mark the succession. As has been stated in the discussion of the histological picture the chondroid or fibroid metamorphosis of n. p. more seems to be the expression of a vital cellular activity than that of a degeneration. However, these processes have been included in the schedule as being the precursors of real degenerative phenomenons. The degenerative changes in a. f. result in different kinds of interruptions in the continuity which have been called ruptures in this schedule. They may be total or partial. They may be localized ventrally, laterally or dorsally. In all these cases they may result in dorsal protrusions (the ventral and lateral ones only after an interlamellar dissection in the dorsal direction). Finally these protrusions may be of two different types, of which type I is the result of a total and type II of a partial rupture of a. f.

The schedule also includes *spondylosis deformans* and allied conditions (*osteochondrosis vertebrae* and others). The changes in the two components of the disc on one hand and in the tissues adjacent to the disc on the other constitute the spondylosis. The broken arrows indicate that ventral disc protrusions or dorsal ones of type II have been observed in some cases of spondylosis. Finally the schedule also includes

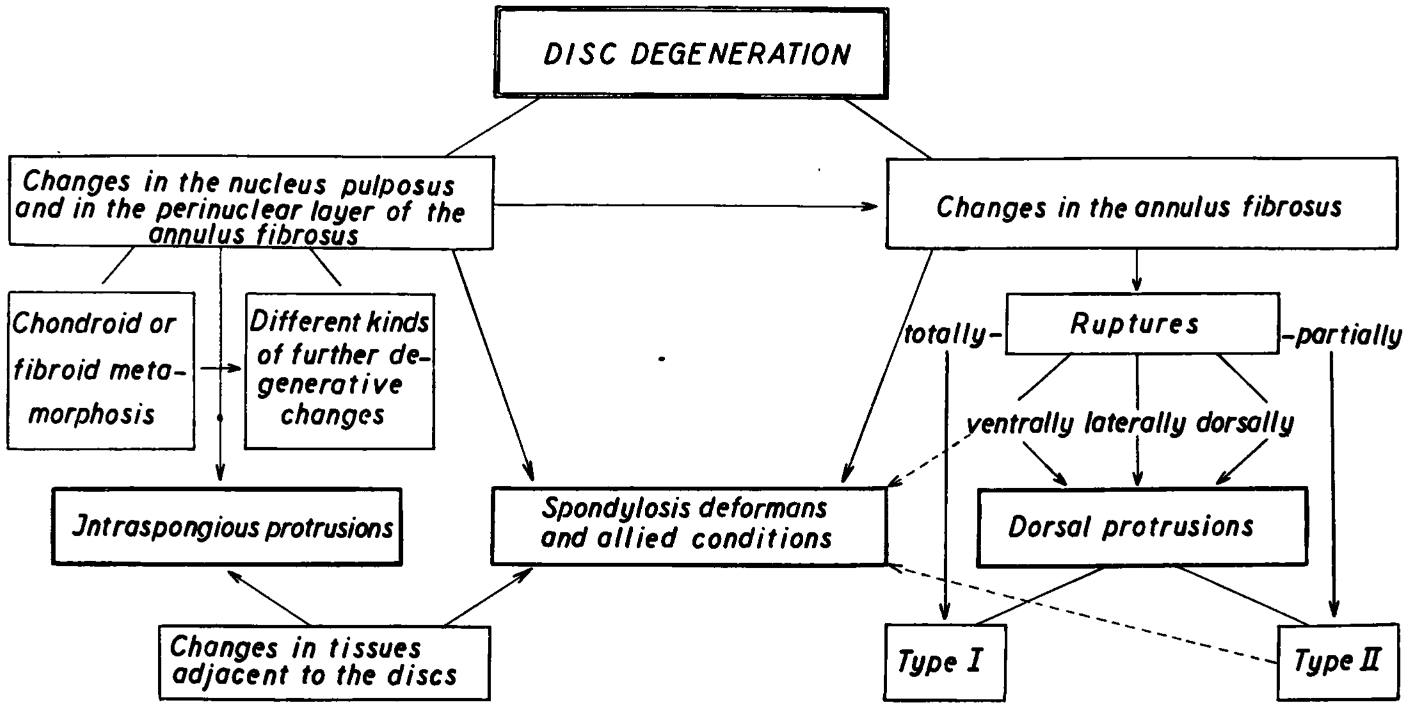

Fig. 8. Disc degeneration in dog.

intraspongious prolapses resulting from the combined changes in the disc and its environment.

In accordance with the title of this work the conditions in the so-called *enchondrosis intervertebralis* will now be discussed. *The author's morphological investigation has shown that the disease that has been thus denominated since Dexler is identical to the kind of disc degeneration that manifests itself as inter alia dorsal protrusions of type I.* This disease is found in the breed group which has been called the chondrodystrophoid one in accordance with the statistical study. In this chapter the question was introduced whether the morphological picture found and the disposing factor found might be synthesized into a hypothesis on the pathogenesis of this kind of disc degeneration. The disposing factor found has been assumed to consist of certain chondrodystrophoid traits in the constitutional type of the most exposed breeds. Thus the question is: May these chondrodystrophoid traits provide an explanation of the tendency to disease of the discs?

A priori it may seem difficult to give an answer to this question as the causal and formal genesis of chondrodystrophia has not yet been satisfactorily examined. However, the following hypothesis, based on the oponion of *Wilton* (1933) seems to be acceptable. The histological process in chondrodystrophia is characterized, as is that in rickets, by an abnormally slow differentiation which affects especially the tissues of the highest growth energy, i. e. the least differentiated ones.

The disc shows a successively reduced degree of differentiation from the periphery towards the centre. The changes during the development of the disc in chondrodystrophoid dogs begin centrally in the portion in which the n. p. and the perinuclear layer of a. f. merge into each other. This primary change — the chondroid metamorphosis — begins in an early stage, takes place swiftly and is systematically extended in the vertebral column. It seems reasonable that the cellular activity which characterizes this process might be an expression of an abnormally low differentiation of the concerned tissues. At least during the new-born stage the perinuclear layer of a. f. shows morphological signs of such a low degree of maturity in these dogs.

In a study of the embryology of the disc in man *Prader* has presented it in an outline which has been transformed by the author into the following schedule:

In an early stage we find, beginning with the outer part a mesenchyme with an indication of a lamellar structure, perichordal precartilage and *chorda dorsalis*. In a later stage the fibrous and lamellar character of the outer layer is still more accentuated and the middle layer has become a hyaline cartilage. During the next stage the inner part

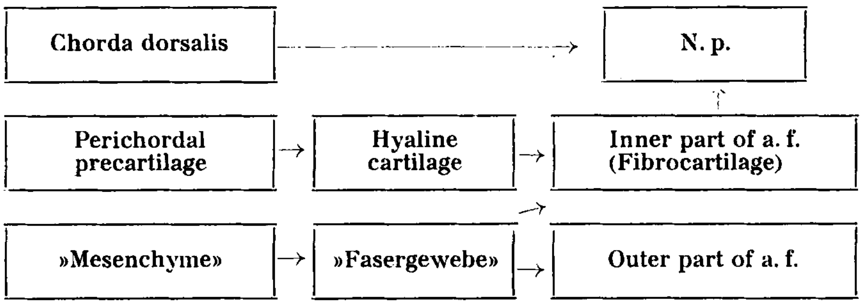

Fig. 9. Schematic interpretation of *Prader's* observations concerning disc embryology in man.

of a. f. has been formed by a united action from these two layers. At last this inner layer of a. f. and the *chorda dorsalis* contribute to the final n. p.

During an intermediary stage the disc thus shows a hyaline cartilage that contributes to the formation of both the perinuclear layer of a. f. and the n. p. If the same applies to the conditions in dog it might be assumed that the chondroid metamorphosis is the result of a detention of this final embryologic stage or of a dedifferentiation.

The chondroid metamorphosis constitutes an early discernible difference between the breeds that are especially exposed to disc prolapse and other dogs. The reason for this fact is of course not of a mechanical but of a constitutional nature. The above interpretation is a hypothesis of the rôle of constitution in this respect.

Many observations have indicated that the disc degeneration of the chondrodystrophoid dogs is a systemic disease and not a local, mechanically conditioned process: the multiplicity of the prolapses and the extensive frequency of other degenerative phenomenons in the vertebral column, also in the portion between discs 7—14 which is protected against prolapses. The chondroid metamorphosis is the base of the systemic character of the disease. During the following stages, however, mechanical factors will characterize the picture and be of decisive importance as to which portions of the vertebral column will show the most serious expressions of disc degeneration.

As, during an early stage, the useful plasticity of the n. p. gets lost it also loses its ability to function as a shock absorber. It is also probable that the ability of the disc to provide for its nutrition is reduced, because of a reduction of the pumping effect of movements. All these things of course ought to be able to result in a traumatic effect on the disc even by normal movements, especially on a. f.

Bradford and Spurling also hint that the injuries to the annulus are to a great extent the result of the failure of the nucleus to function properly. This conception of the primary rôle of the n. p. in disc degeneration in man is also presented by *Hirsch* (1951), while *Eckert and Decker* (1947) and *Key and Ford* (1948) maintain the primary rôle of the a. f. in this connection. By means of rat experiments *Lindblom* (1952) has shown that a constant unilateral compression of the discs may result in a degeneration of the annulus without any concurrent change in the nucleus. In non-chondrodystrophoid dogs the centrifugal character of the disc degeneration has not been as strikingly observed as in the chondrodystrophoid ones. The question of the rôle of the mechanical factors in this connection is an interesting one. This is shown in Figure 4. Disc degeneration as expressed by prolapses has most often been observed in the transition between the thoracic and lumbar regions, while the calcifications have a more even distribution though they have been most frequent in the region of discs 13—19. The localization of the prolapses thus coincides more with the thoracolumbar kyphosis of these dogs, especially that of the dachshund, while the localization of the calcifications coincides more with the most important centre of movement of the vertebral column, as this has been established by *Slijper*.

The extension of the calcifications is more uniform and systematic than that of the prolapses. Thus, disc calcification, secondary to degenerative changes is more in accordance with the chondroid metamorphosis than with the protrusions. This circumstance together with the high frequency of calcified disc centres supports the conception that disc degeneration is a centrifugal process.

A. f.-ruptures are of course most severe and most frequent in the places where the mechanical stresses which predispose to ruptures of a. f. exist. It is an interesting fact that while in man the disc degeneration is most frequent in lordotic portions of the vertebral column (*Thieme, Friberg*) the case is quite the contrary in dog. *Lindblom* (1952) has shown that when constant pressure is applied to one side of the disc, the other consequently being stretched, degeneration and ruptures of a. f. will occur on the pressure side. This fact should indicate that the definite tendency to dorsal protrusions in the chondrodystrophoid dogs should mainly be the result of a pressure. In this connection the fact that a. f. is so much stronger ventrally than dorsally probably is of a certain importance. Thus, it is reasonable to presume that the portions of the vertebral column, which show the highest frequency of protrusions are those where dorsal disc compressions most often or most severely exist. The small discrepancy between the localization of disc calcifications and that of disc protrusions should then indicate that the most important centre of movement is not identical with the portions where dorsal disc compressions most often or most severely exist. This latter portion, however, is in stead coinciding with the thoracolumbar kyphosis. In the discussion of this subject we ought to point out that we do not know how the circumstances should be in the portion of the discs 7—14 if *lig. conjugale costarum* did not exist.

Perhaps it should also be discussed if the disc calcification that is so very common in chondrodystrophoid dogs is the result of degeneration or of a general disturbance in calcium metabolism. Concerning man *Sandström* (1951) has classified calcifications in the soft tissues of the body as belonging to one permanent and one impermanent type. The latter type of disc calcification he considers to be a certain disease condition of the same type as in D-hypervitaminosis or in *myotendinitis calcarea*. *Calvé and Galland* (1930) showed that calcium could exist in human discs as carbonate, phosphate or urate. A summary chemical analysis of calcified disc material from dachshunds did not show any uric acid as has been mentioned on page 85.

Concerning dog a roentgenological disappearance of calcium in the discs has been observed (*Pommer*, *Olsson*). In the case of *Olsson* it was a question of a rupture of a. f. through which the calcium disappeared. In the author's material nothing indicates that the calcium may disappear otherwise than through a rupture. On the other hand the histological investigations have shown that calcified discs are always the seat of degeneration. According to the textbooks calcification is a common regressive phenomenon in above all hyaline cartilage. From that viewpoint a dystrophic calcification of a chondroid tissue is more reasonable than that of a fibroid one. Of course, it is not excluded that the calcium metabolism of these dogs should show a tendency to calcification as soon as the local conditions are favourable to such a process. However, calcification processes in other tissues do not seem to occur more often in these dogs than in others. As is known, metastatic calcifications are above all to be found in connection with hyperparathyroidism and D-hypervitaminosis (*Selye* 1948). Neither do some observations of chondrodystrophia and parathyroid glands (*Dietrich*, *Wilton*) point to metastatic calcifications in this connection. How the opinions of *Crew* and *Adametz*, which hold hypoplasia of the pituitary gland responsible for chondrodystrophia may be compatible with the possibility of metastatic calcifications in chondrodystrophoid individuals is obscure. Later findings on the relationship between the pituitary and parathyroid glands (*Törnblom* 1949) do not give any definite answer to this question. The uncertainty of these points further stresses the desirability of endocrinological studies of the dogs which have been characterized as chondrodystrophoid in this work.

The form of disc degeneration that leads to prolapses of type I is, according to this interpretation, a systemic disease with its gravest expressions in the portions which are exposed to the greatest mechanical stresses. However, no observations have been made on the dogs especially exposed to disc degeneration that indicate any significant general tendency towards dieseases of the supporting tissues. Thus, for instance *Forssell* (personal communication) is of the opinion that the dachshund is conspicuously seldom afflicted by arthroses. Neither are these breeds especially disposed towards meniscus injuries (*Paatsama* 1952). The reverse ratio between spondylosis and type I disc prolapse also agrees with these observations.

SUMMARY

This paper is a systematical and pathologic-anatomical study on disc degeneration in dog, performed during the years 1949—1952 at the Department of Pathology at the Royal Veterinary College in Stockholm.

In a historical survey (Chapter I) of disc degeneration and disc prolapse in dog, other animals and man the author finds an obvious parallelism. By and by it has been realized that degenerative changes in the discs may result in dorsal protrusions in dog as well as in man. Thus the intraspinal processes, which as far as man is concerned have been designated as inter alia "ventral extradural chondromas" and which as far as dog is concerned have been conceived in the notion *enchondrosis intervertebralis* (e. i.) as tumorous cartilaginous growths have got their explanation. For that reason the author has left this denomination and instead used disc degeneration and disc prolapse (synonymously disc protrusion). The disease e. i. in dog has, however, been interpreted as an ailment, primarily localized to the discs since the pioneering researches of *Dexler* in the late 1890's.

In a survey of the anatomy and physiology of the vertebral column (Chapter II) the author presents some main views on this subject, based on literature and own observations. The question of which portion of the vertebral column is subjected to the greatest mechanical stresses is discussed with regard to *Zschokke's* conception of the vertebral column as a truss and *Slijper's* comparison with a bow and string. Concerning the anatomy of the discs the author shows that the share of the discs in the length of the vertebral column is considerable in man (25 % according to *Bradford and Spurling*) and in dog (17.44 % according to the author's own investigations). Measurements on cat and horse gave the figures 11.81 and 11.13 %. In this respect a statistically highly significant difference was found between dog and cat or horse. Disc lesions seem to be of no importance in horse and cat. This fact may perhaps indicate a positive correlation between disc length (height of disc in man) and disposition for disc lesions. In this chapter the author also presents *lig. conjugale costarum*, forming a roof over each of the discs 7—14 (Fig. 13) as an anatomic protection against dorsal prolapses in this portion.

In Chapter IV the author shows that a statistically highly significant difference in the frequency of dorsal disc protrusions exists, the disease being more often found in the breeds dachshund, French bulldog and pekinese than in others (Table 3 a) and that there is no difference between dachshunds of different colour of the hair (Table 3 b). The size of the French bulldog is practically square, while that of the others is pronouncedly low-rectangular (Table 5). The author will not take this fact as a substantiation of the belief that disc degeneration should primarily be the function of a mechanical factor conditioned by the size. Instead certain chondrodystrophic traits are mentioned as the common denominator of the particularly disposed breeds. In a series of new-born puppies of different breeds the author is able to trace a modification of the histology of the endochondral ossification in the breeds dachshund and French bulldog in the direction of the changes in chondrodystrophia (achondroplasia). For this reason the breeds disposed towards disc degeneration are denominated as "chondrodystrophoid" and the others "non-chondrodystrophoid".

No sex disposition seems to exist. The frequency of disc prolapses grows with the age of the animals (Fig. 2).

In Chapter V an account is given of macroscopic observations on 561 dogs dissected post mortem. In 93 of these cases a total of 232 prolapses was found, distributed along the vertebral column as shown in Figs 4 and 5 and Table 7.

Cervical disc prolapses were found in 15 cases, 12 of which also showed thoracolumbar ones. 2 of these cases of cervical prolapse showed clinical symptoms from the disc injury (e. g. Case V, Chapter VII). The region of the discs 7—14 did not show any prolapses. In the author's opinion the probability of finding prolapses in this region is 0 because of the existence of the *lig. conjugale costarum.* That this ligament is a protective mechanism is shown by the fact that the precursors of disc prolapse are common in this portion too.

Thoracolumbar disc protrusions were found in 90 cases (96.9 ± 1.8 %). Most exposed to prolapses is the disc between Th 13 and L 1. Table 8 shows the frequency of disc protrusions in different parts of the thoracolumbar region.

The prolapses are of two types. *Type I* assumes rather large size — up to the main part of the vertebral canal's profile or, if the spread has occurred in a more horizontal direction, the length of a vertebra. It is characterized by an uneven, rough surface which as a rule is adherent to the dura in a fibrous or fibrinous way, or irregular form, of brittle consistency and greyish-red to greyish-yellow in colour. *Type II* is characterized by smaller proportions, even surface, circumscript and regular form, firm consistency and greyish-white to greyish-yellow in colour. They are placed either as a median ridge-shaped elevation of the *lig. longitudinale int.* or as bud-shaped protrusions on the side of this. Prolapses of type I are found in dogs of the chondrodystrophoid type and in comparatively young dogs. Prolapses of type II, however, seem to be able to affect all breeds and considerably older individuals. In other words they seem to be more or less definitely senile phenomenons. In the former case the clinical picture is more acute and severe, while type II prolapses show slight symptoms or no symptoms at all.

The prolapses are always preceded by a disc degeneration. The ruptures are total in type I, partial in type II. They are more often dorsomedian than dorsolateral. They may be ventral with an interlamellar dissection in the dorsal direction. Sometimes they are in the immediate vicinity of the bodies of the vertebrae and if this is the case they are more often found near the vertebra next ahead. They may be observed with the naked eye or be so thin and winding that it is impossible to follow their course otherwise than microscopically by serial sections.

Disc degeneration exists in the spinal column much more generally than the number of prolapses allows us to suppose. Disc degeneration is preceded by certain systemically extended age changes. In non-chondrodystrophoid dogs the mucoid n. p. is successively changed into a more fibroid one. Only after the age of 7 it is statistically highly significant that the probability to find a mucoid n. p. is smaller than that of finding a fibroid one (Table 13). In the chondrodystrophoid dogs, however, it is statistically highly significant that the majority of the individuals have lost their mucoid nucleus already in an age of 1 year, this tissue being replaced by a more chondroid one (Table 12). The most usual expression of disc degeneration in chondrodystrophoid dogs is a calcification of the central portion of the disc. The present material shows 1194 calcified discs, distributed according to the curve in Fig. 4. The distribution differs somewhat from that of the protrusions. The thoracic region, especially the region between discs 13—19, is the region most exposed to calcification. The degeneration also assumes other forms, which may be observed macro- or microscopically, one of which resembles the "brown degeneration" in man. The author found this type of degeneration only in discs with total ruptures. In this connection it was possible to find a benzidine-positive pigment in the tissue, for which reason the author is of the opinion that this phenomenon is of haemoglobinogenic nature.

The author also discusses the rôle of the discs in some other diseases in the vertebral column. In this connection he has found that changes in shape are most uncommon in dog. Then an account is given of a case of intraspongious prolapse with clinical symptoms, possibly derived from this prolapse. Finally the author touches upon the *spondylosis deformans* and concludes that the kind of disc degeneration which will finally result in prolapses of type I has nothing in common with *spondylosis deformans*, while the kind of disc degeneration, that results in prolapses of type II has some points in common with the spondylosis complex.

In Chapter VI the author gives an account of the histological background of the genesis of prolapses. This account is given in the form of a continuous description of the discs in different age groups.

The disc of the new-born dog shows independently of breed three histological components. In the centre the low-differentiated n. p., next an inner layer of a. f. the character of which is fibro-cartilage and whose perinuclear layer shows a lower degree of maturity than the more peripheral one and finally the outer highly differentiated lamellar portion of a. f. In chondrodystrophoid dogs the lower degree of maturity of the perinuclear layer is more conspicuous than in non-chondrodystrophoid ones.

In dogs of the non-chondrodystrophoid type the age development of the disc is characterized by a successive collagenization of n. p., which in this connection is regarded as a maturation process. This maturation is often disturbed by degenerative changes both in n. p. and a. f. Separations and ruptures in the dorsal a. f. may result in "intradiscal protrusions" of material from the centre with a bulging of the outer part of a. f. (protrusion of type II).

In dogs of the chondrodystrophoid type the age development of the disc is characterized by an early initiated, very accelerated transmutation of its central portion into a tissue of a more chondroid nature. This metamorphosis takes place with signs of both progression and regression of n.-p.-cells and the cells of the perinuclear layer of a. f. To this picture further degenerative changes of the n. p. and of the whole a. f. are soon added. Among them the dystrophic calcification plays an important part. As a result of comprehensive disturbances of the continuity of the a. f. material from the inner portion of the disc may by and by force its way mainly in the dorsal direction. Total ruptures give protrusions of type I. The protrusions are acute, subacute or chronical. As a rule they are accompanied by big haemorrhages and an extensive inflammation, which is most often of the foreign body reaction type with mononuclear and polynuclear phagocytic cell elements. The prolapses may diminish in volume through a reabsorbing activity from this granulation tissue and through reduction of the inflammatory reaction.

An increase in volume may occur on account of a secondary rupture of a prolapse bridged by connective tissue (Case III, Chapter VII). The small signs of a cellular progression observed are probably of secondary importance in this connection.

The author considers that, from the principal viewpoint, the metamorphosis of the n. p. is the result of a cellular activity and that the tissue formed is a vital structure. Thus, the progressive tendencies ascribed to the disease called e. i. should have taken place within the disc before the disease has resulted in rupture of the a. f. and prolapse.

Chapter VII is a casuistic illustration of the connection between certain clinical symptoms and the patho-anatomical picture in disc protrusion. See summary on page 101.

In chapter VIII the author uses a schematic table (Fig. 8) on disc degeneration in dog in order to discuss the kind of disc degeneration which results in prolapses of type I (*enchondrosis intervertebralis* according to earlier nomenclature). The thought is introduced *that* the chondrodystrophoid character of the breeds concerned is the basis of the chondroid metamorphosis, *that* this loss of plasticity in the n. p. gives degenerative changes in above all the a. f. as a secondary result, *that* they by and by result in ruptures and prolapses, *that* these serious expressions of disc degeneration are localized to such portions of the vertebral column in which the greatest mechanical stresses are to be found and — *that* thus the nature of disc degeneration is that of a systemic disease.

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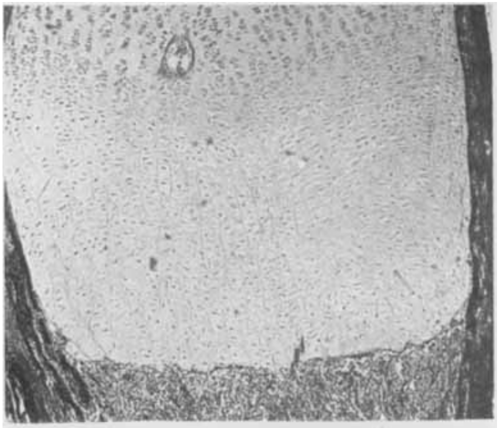


Fig. 10. (P. 1685/50) Newborn poodle. Costo-chondral junction. Ordinary endochondral ossification with well-defined zones in the cartilage and a linear border between cartilage and bone. van Gieson. 28×.

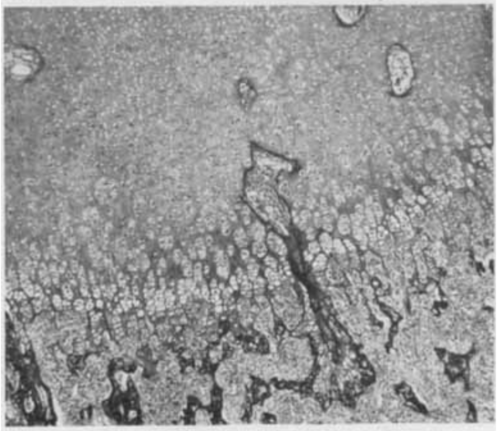


Fig. 11. (P. 1644/49) Newborn french bulldog. Costo-chondral junction. Modified endochondral ossification. The zone of maturing cartilage shows rather undeveloped column structure, irregular border between cartilage and bone with descending cartilaginous buds, unopened cell capsules and rich vascularization of the cartilage. The newly formed trabeculae are short and thick. van Gieson. 28×.

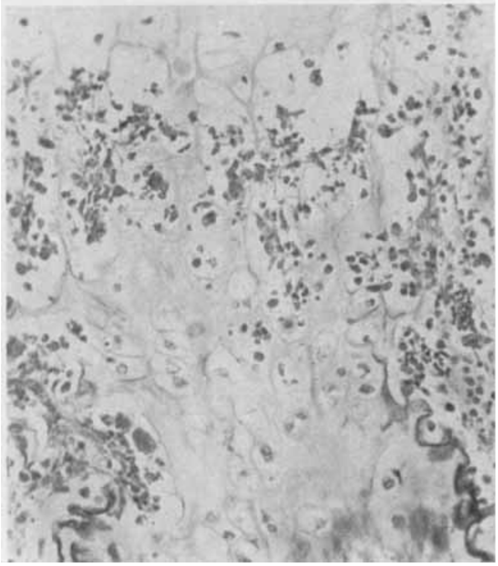


Fig. 12. (P. 1452/49) Newborn dachshund. Costo-chondral junction. The centre of the picture shows an isolated cartilage island, surrounded by newly formed bone. This cartilage island shows unopened cell capsules. van Gieson. 200×.

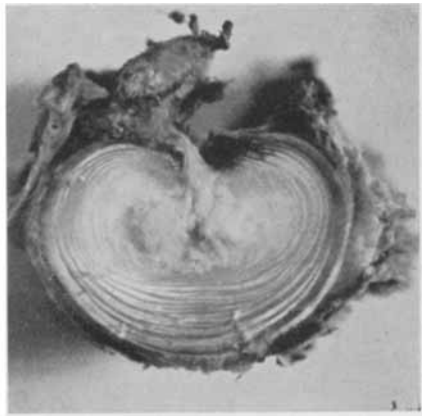



Fig. 13. (O. 157/50) Dachshund, 2.5 years old. Disc 10. The broad *lig. conjugale costarum*, forming a roof over the disc, protects the spinal canal against protrusions in this region. Nucleus is the site of a dystrophic calcification with tendency to extend in dorsal direction.

Fig. 14. (O. 245/50) Dachshund, 6 years old. Disc 21. Protrusion of type I. The picture shows the large dimensions of the protrusion and demonstrates clearly its origin from nucleus. The a. f. rupture is situated close to the right side of the *lig. longitudinale int.* Nucleus is the site of a calcified necrosis and has lost its normal shape.

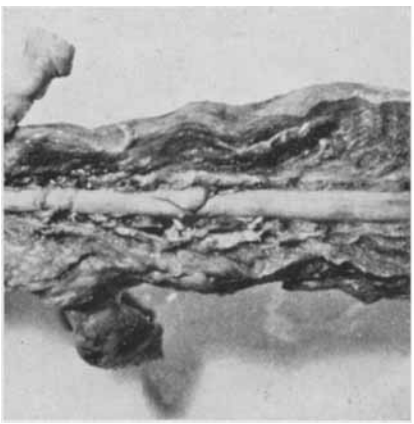
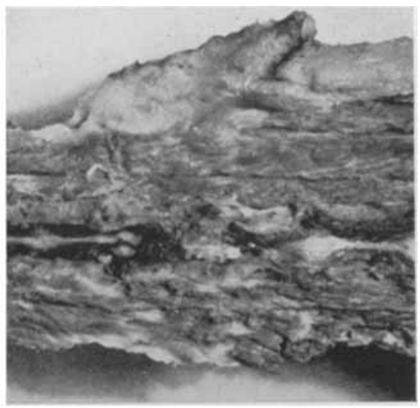



Fig. 15. Same dog as in Fig. 14. Dorsal view of the back with the vertebral arches taken off. The protrusion is situated to the right of the spinal cord and has formed a vault over it.

Fig. 16. (O. 662/48) Dachshund, 5 years old. Dorsal view of the thoracolumbar region with the vertebral arches and the spinal cord taken off. On disc 19 there is a long, broad and low protrusion of type I with rough, uneven surface.

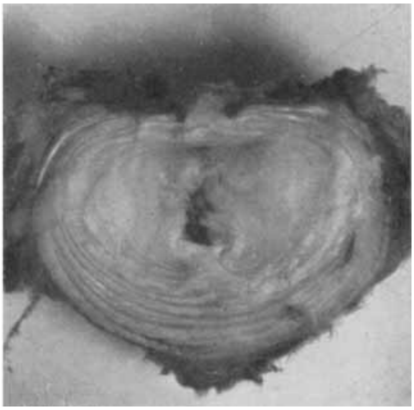
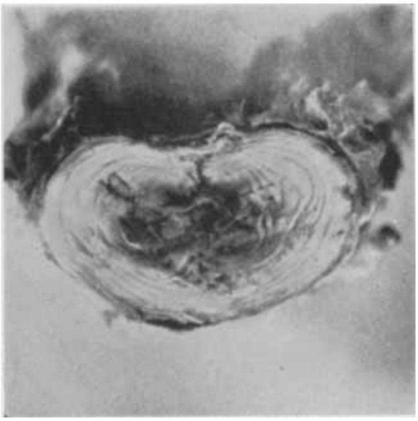


Fig. 17. (O. 765/50) Dachshund, 4 years old. Disc 22 with a calcified centre and a dorsomedian rupture of a. f. The protrusion is of type I with loose consistency and rough, uneven surface. An interlamellar dissection of calcified material is seen to the left of nucleus, emanating from a ventral rupture of the inner layer of a. f. This rupture, however, is not seen in this picture.

Fig. 18. (O. 808/50) Dachshund, 11 years old. Disc 22 showing a ventral rupture of the inner layer of a. f., through which nucleus is evacuated. Light, calcified material still remains in nucleus and the same material can be followed as circular interlamellar dissections in both directions, resulting in a comparatively small dorsomedian protrusion.



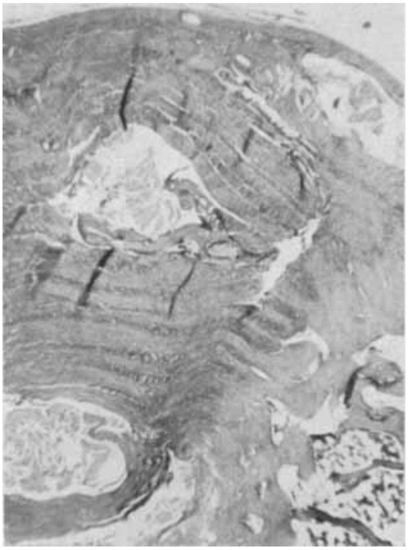


Fig. 19. (O. 304/50) Dachshund, 7 years old. Disc 23, site of a severe nucleus degeneration ("brown degeneration" type) and two main ruptures of a.f. The dorsomedian rupture is T-shaped, causing a slight protrusion to the right of the median plane.

Fig. 20. (O. 682/51) Dachshund, 7 years old. Sagittal section through the dorsal annulus, the dorsal part of nucleus and a part of the vertebral body (seen to the right). Nucleus is the site of a calcified necrosis. From the centre of a. f. there is a winding prolapse route to a dorsal protrusion via among other things a rupture of the lamellae close to the vertebral body. The connection between nucleus and prolapse route is not seen in this section. van Gieson. 28×.

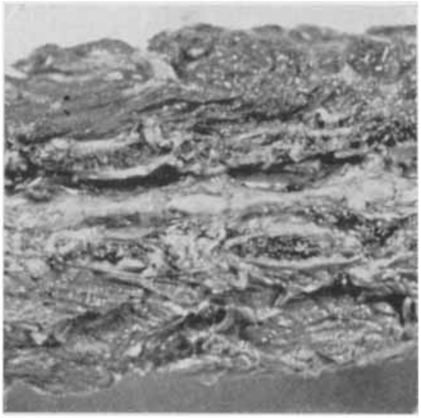


Fig. 21. (O. 11/50) Swedish hound, 7 years old. Dorsal view of the lumbar region with the vertebral arches and the spinal cord taken off. Disc 22. Protrusion of type II as a threshold-like formation between the two vertebral bodies.

Fig. 22. (O. 945/50) Dachshund, 11 years old. Dorsal view of the thoracolumbar region with the vertebral arches and the spinal cord taken off. Disc 18 shows a protrusion of type II as a median ridge-shaped elevation of the *lig. longitudinale int.*

Fig. 23. (O. 141/51) Rottweiler, 10 years old. Dorsal view of the lumbar region with the vertebral arches and the spinal cord taken off. Disc 18 shows protrusions of type II- one as a median ridge-shaped elevation of the *lig. longitudinale int.*, the other as a bud-shaped protrusion to the right of the ligament. The picture shows the even surface and the circumscript and regular form.

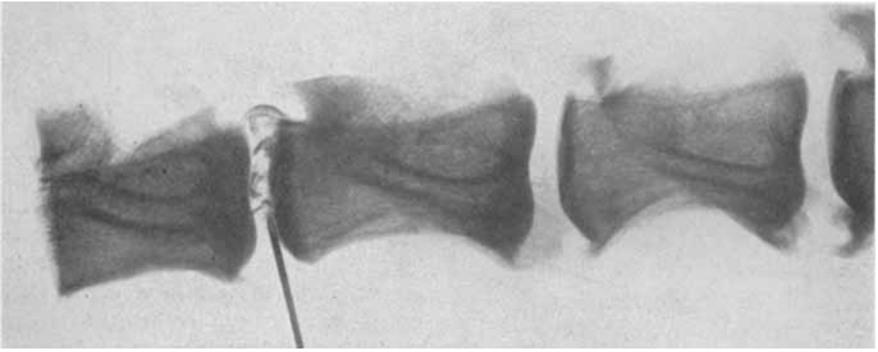


Fig. 24. Same dog as in Fig. 23. Roentgenogram, showing a protrusion of type II on disc 23. The connection between the disc centre and the protrusion has been established by means of thorotrast discography. Slight ventral osteophytes on the surrounding vertebrae, more pronounced regarding the other intervertebral spaces.

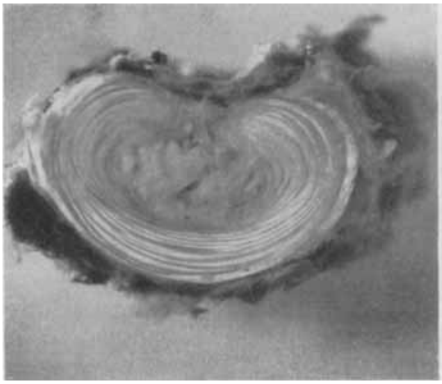
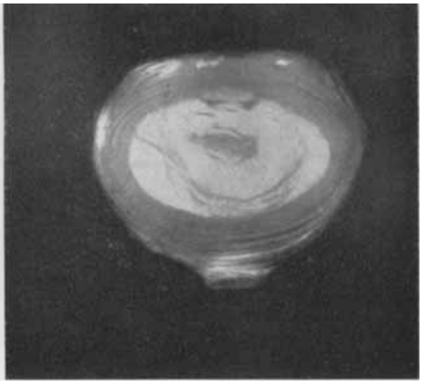



Fig. 25. (O. 274/50, case II in chapter VII) Dachshund, 9 years old. Disc 18. Chronic protrusion of type I through a dorsomedian annulus rupture. Fibrous adhesion between the dura and the protrusion.

Fig. 26. (O. 712/49) Dachshund, 6 years old. Disc 2 with calcified nucleus. The calcified material forms a broad intermediate ring in the disc.

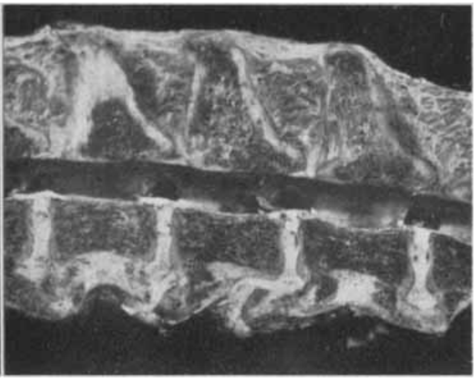



Fig. 27. (O. 381/50) Dachshund, 4.5 years old. Sagittal section through disc 20 and second lumbar vertebra showing an intraspongious protrusion of calcified disc material.

Fig. 28. (O. 369/50) Boxer, 11 years old. Sagittal section through lumbar region. Generalized *spondylosis deformans*. Explanation given in the text on page 71.

Fig. 29. (O. 73/50) Dachshund, 12 years old. Disc 22 with a total ventral annulus rupture, thickening of the outermost lamella and slight osteophytes on the vertebral body concerned.

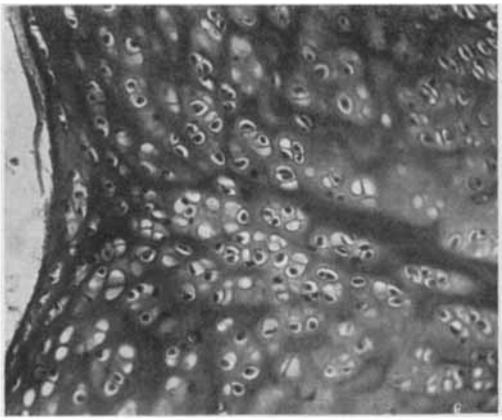


Fig. 30. (P. 1644/49) Newborn french bulldog. Sagittal section through the epiphysis of a lumbar vertebra. The picture shows the arrangement of the cartilage-cells with a funnel-shaped retraction of the border of the nucleus and the dense axial intercellular passage, indicating the foetal location of *chorda dorsalis*. van Gieson. 200×.

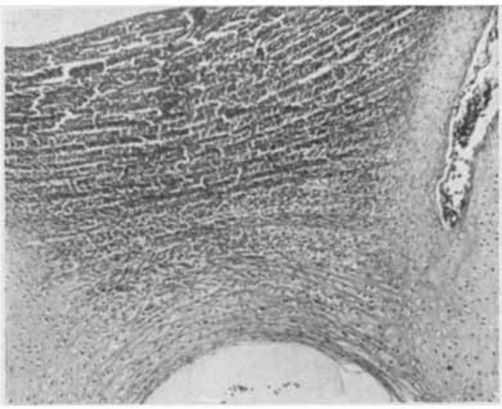


Fig. 31. (P. 220/50) Newborn afghanian. Sagittal section through the dorsal part of a lumbar disc. The outer relatively highly differentiated annulus occupies the greatest part of the annulus. The inner part also gives a rather mature impression. The outermost part of the annulus is vascularized. van Gieson. 100×.

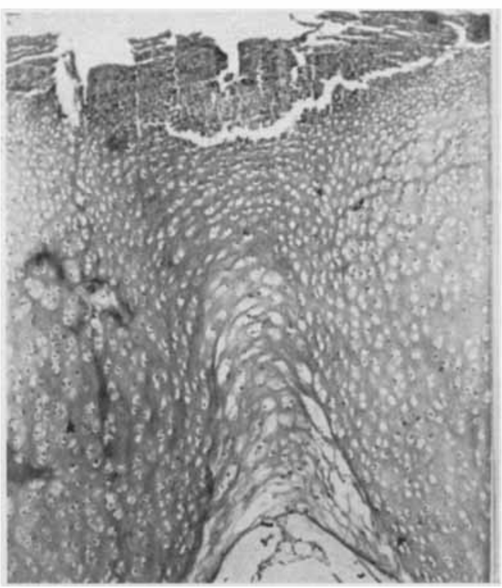


Fig. 32. (P. 1644/49) Newborn french bulldog. Sagittal section through the dorsal part of a lumbar disc. This picture shows that the inner low-differentiated annulus occupies the greatest part of the annulus. van Gieson. 100×.

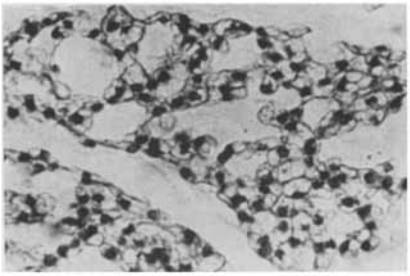
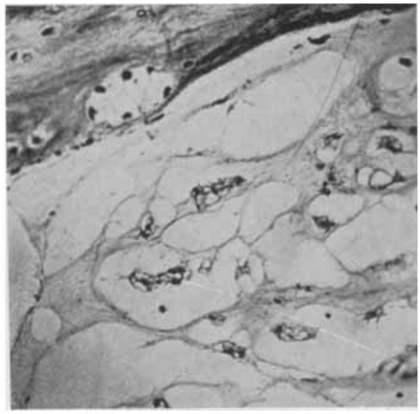
 

Fig. 33. (P. 774/50) Newborn guinea-pig. N. p. from a lumbar disc, showing the uniformity of the cell picture and the vital nature of the cells. van Gieson. 400×.
Fig. 34. (O. 498/50) Dachshund, 2 months old. Nucleus, just on the border of annulus, from a cervical disc. The picture shows the characteristic nucleus cells with their vesicular cytoplasm and the intercellular substance, sparse in collagen fibres, but rich in "chromotrope substance". Azan stain. 200 ×.

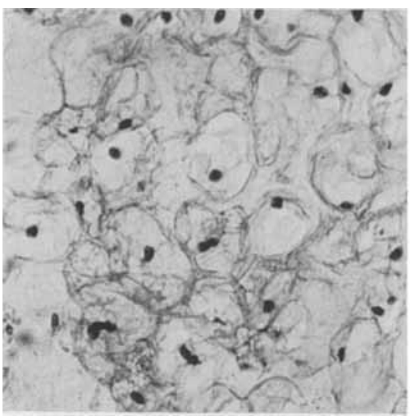
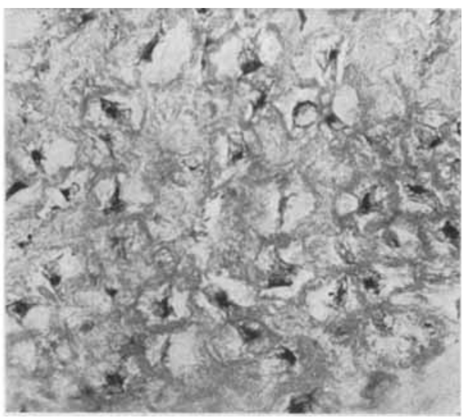
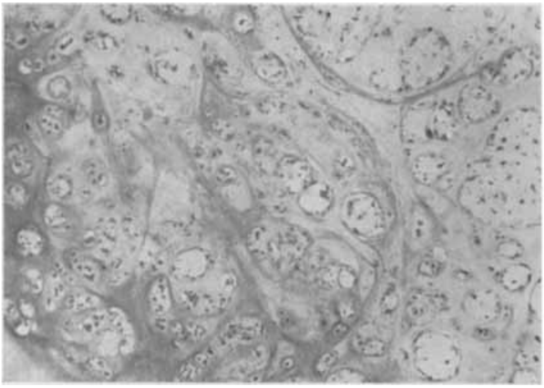
 

Fig. 35. (O. 416/50) Collie, 2 years old. N. p. from disc 6, showing vital cells of characteristic original type. The intercellular substance, however, is changed with increased number of collagen fibers and decreased amount of "chromotrope substance". van Gieson. 400×.
Fig. 36. (O. 485/50) Airedale terrier, 10 years old. N. p. from disc 9, showing still vital cells with a certain similarity of fibrocytes and an intercellular substance, rich in collagen fibers. van Gieson. 400 ×.



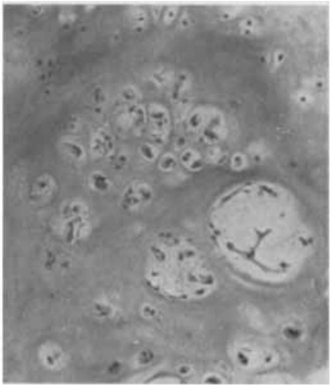


Fig. 37. (O. 200/50) Dachshund, 7 months old. N. p. from disc 9. Chondroid metamorphosis with increased intercellular fuchsinophilia and groups of vital, dividing cells, arranged in a manner, reminding of that of cartilage. van Gieson. 100×.

Fig. 38. Same as in Fig. 37 in greater magnification. Note how some cell groups still have certain traits of original nuclear material, while in others the cellular pattern reminds of cartilage. van Gieson. 200×.

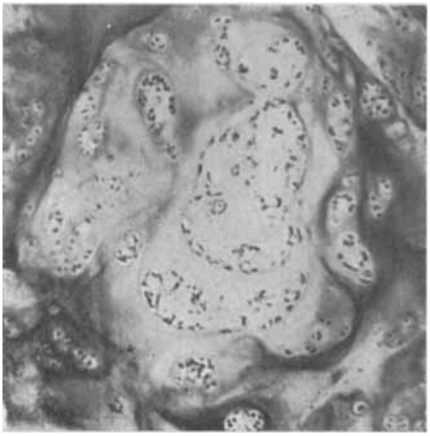


Fig. 39. (O. 140/50) Dachshund, 4 months old. N. p. from disc 2. Chondroid metamorphosis. The large cell mass in the centre of the picture still has certain traits of original nuclear material. The picture gives as a whole the impression of a brisk cellular activity. van Gieson. 100×.

Fig. 40. Same as in Fig. 39 in greater magnification. The picture shows the definite cartilage-like cell pattern, except of one small group of a more original nuclear character. van Gieson. 200×.

Fig. 41—43. (O. 874/51) Dachshund, 6 years old. Cell division pictures of propably both mitotic and amitotic nature. Hemalum-eosin. 400×. (The right picture 1 000×.)

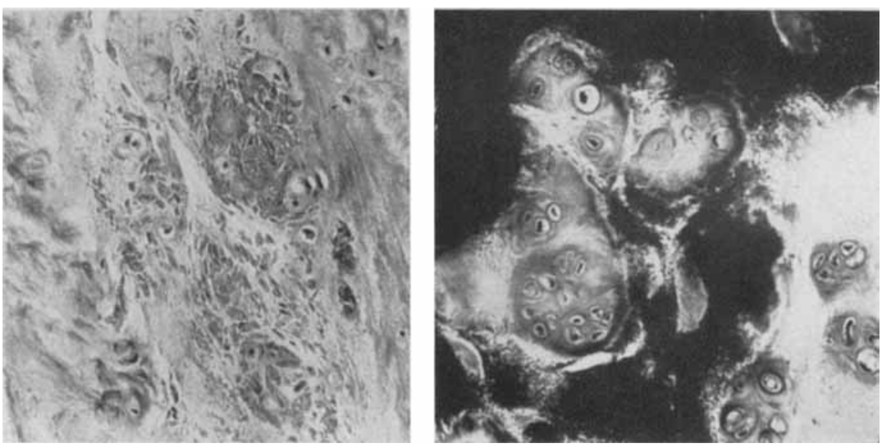


Fig. 44. (O. 238/50) Poodle, 1 year old. Disc 19. Just on the border between n. p. and the perinuclear layer of the a. f. there is foci with strongly "picrinophilic" often banana-shaped fragments in and around the cell-groups, probably due to a break-down of cells. van Gieson. 200×.

Fig. 45. (O. 839/50) Dachshund, 3 years old. Disc 17. Granular calcification of the intercellular substance on the border of uncalcified tissue. The calcium salts are deposited in the material between the cell-groups, thus tending to isolate them. The cell-groups show degenerative changes. Palmgren's silver stain. 200×.

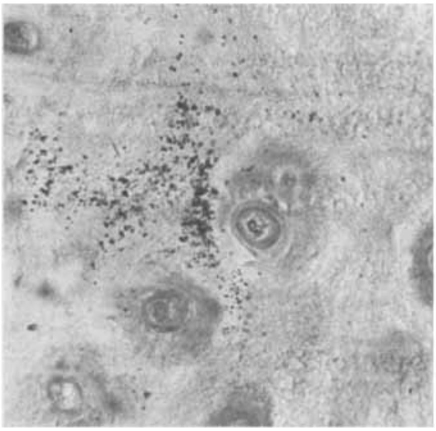
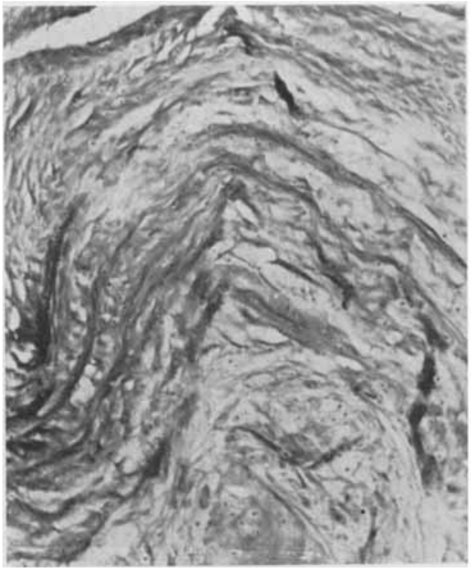


Fig. 46. (O. 468/50) Dachshund, 12 years old. Nucleus from disc 19. The picture shows karyolysis and granular degeneration of the intercellular substance. Moreover, there is a great amount of small benzidine-positive granules in the intercellular mass ("brown degeneration"). Lepehne's benzidine test. 400×.

Fig. 47. (O. 668/50) Dachshund, 11 years old. Annulus from disc 9, showing a fibrolytic dissolved lamella in the lower part of the picture. Foot and Foot. 400×.



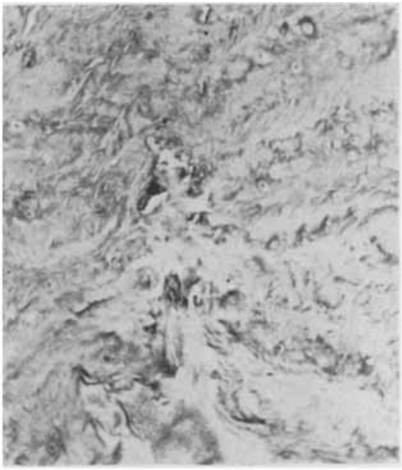
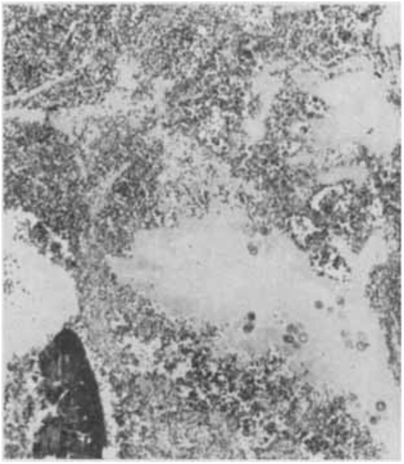


Fig. 48. (O. 110/50) Dachshund, 4 years old. Annulus from disc 15. The picture shows a dorsal bulge of the inner annulus layer, causing an "intradiscal protrusion" of material from the disc centre. van Gieson. 100×.

Fig. 49. (O. 55/51) Dachshund, 4 years old. Annulus from disc 20. Cross rupture of the inner annulus layer, causing a tapering "intradiscal protrusion" of granular material from the disc centre. van Gieson. 100×.



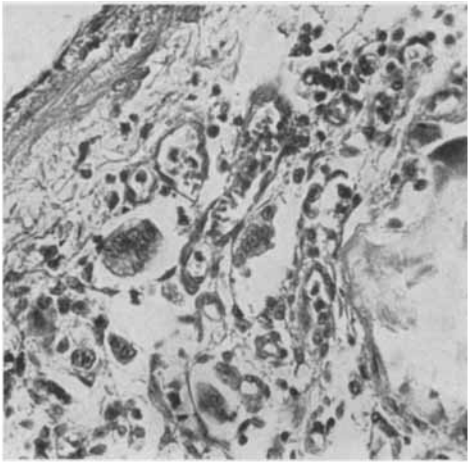


Fig 50. (O. 110/50) Dachshund, 4 years old. Acute prolapse of type I, showing the proportion between the protruded disc material and the haemorrhage. Hemalum-eosin. 100×.

Fig. 51. (O. 245/50) Dachshund, 6 years old. Subacute prolapse of type I. The picture shows to the right a somewhat calcified part of the protruded disc material and for the rest an inflammatory tissue, richly vascularized and containing except of various mononuclear cells, also polynuclear giant cells, indicating a foreign body-reaction. One of the giant cells has a direct continuity to the endothelium of a capillary vascular channel. van Gieson. 400×.

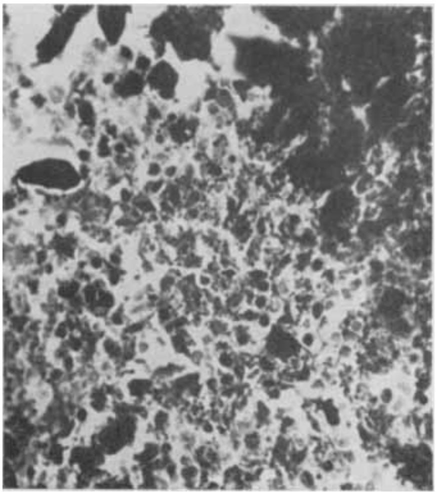


Fig. 52. (O. 682/51) Dachshund, 7 years old. Subacute prolapse of type I, showing fine dark granules in most of the cells, indicating a resorption of calcium. Bock. 400×.

Fig. 53. (O. 274/50) Dachshund, 9 years old. Chronic prolapse of type I. In the lower part of the picture the ruptured *lig. longitudinale int.* is seen with the rupture to the left and the hyaline ligament to the right. Between this and the fibrously thickened dura in the upper part of the picture there is a chronic inflammatory connective tissue with rests of calcified protruded disc material. van Gieson. 100×.

Fig. 54. (O. 55/50) Pekinese, 6 years old. Part of the outermost dorsal lamella from disc 22. The picture shows the probable end stage of a prolapse of type I. The rupture of the outermost lamella is obstructed by chronic inflammatory connective tissue, rich in large mononuclear cells. van Gieson. 200×.

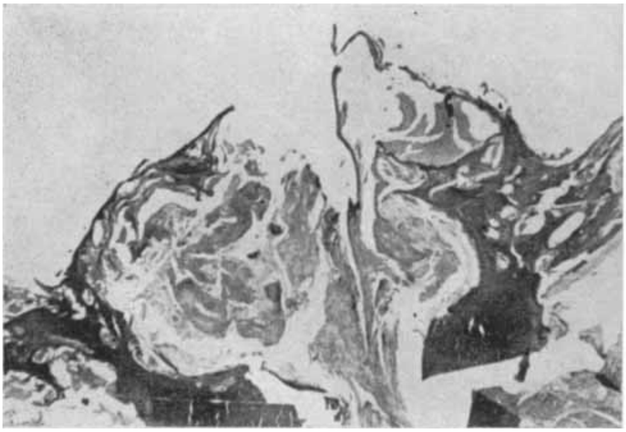


Fig. 55. (O. 96/50, Case III in chapter VII) Dachshund, 5 years old. Disc 19 with a prolapse of type I. The picture indicates the possibility that a protrusion may occur by degrees. In the lower part of the picture the rupture in the strongly hyaline *lig. longitudinale int.* is seen, resulting in a prolapse of disc material. This prolapse has probably been bridged by connective tissue. Through a secondary rupture of that bridge the upper stage then may have developed. van Gieson. 28×.

Fig. 56. (O. 624/50 Case IV in chapter VII) Alsatian, 9 years old. Protrusion of type II from disc 19. The picture shows a bulging of the *lig. longitudinale int.* by protruded disc material. van Gieson. 28×.