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DEGENERATION OF THE INTERVERTEBRAL DISC IN THE CAT

By

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INTRODUCTION

In the three mammals which have been most thoroughly investigated, the dog, cat, and man, the intervertebral discs in certain parts of the vertebral column seem particularly liable to pathological changes. Although anatomical factors such as mobility and weight-bearing are commonly accepted as the cause of this, the manner in which these factors operate remains largely unknown. This obscurity arises partly from a lack of detailed information about the distribution along the vertebral column of the various types of pathological change: in the absence of comprehensive data it is difficult to know what it is that the anatomical factors have to account for. Most of the information which is available concerns the distribution of dorsal (posterior) protrusions. However, *Hansen* (1952, p. 47) found that in the dog the distribution along the vertebral column of calcification, which is a major form of disc degeneration in this species, was not the same as that of dorsal protrusions; similarly in the cat the distribution of ventral protrusions is different from that of dorsal protrusions (*King & Smith*, 1960a, b). This paper reports a comprehensive survey of the macroscopic changes, other than protrusions, which occur in the intervertebral discs of the cat; it will be shown that these changes too have their own particular distribution along the vertebral column. The relationship of these changes to age has also been studied.

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MATERIALS AND METHODS

A total of 110 cats was investigated. The first 50 were adults taken at random; their ages were unknown except that from the degree of fusion of the epiphyses they were believed to be over 2 years old. The second 50 were of known age and represented each year between 2 and 20; some selection was necessary to balance the various ages. These were divided into 4 age groups: 2 to 6, 7 to 10, 11 to 14, and 15 to 20 years, containing 10, 16, 11 and 13 cats respectively. These 100 cats were the same cats as those investigated for ventral protrusions and dorsal protrusions (*King & Smith, 1960a, b, c*). There were also 10 other cats, juveniles, between 1 and 2 years old; this material is used below only in the section on age changes. All the cats were brought to veterinary surgeons for destruction. None was known to be a clinical case of disc protrusion or a similar condition.

In every cat each disc was cut transversely and the cut surface was examined, except for the coccygeal discs of which none was examined. A dissecting microscope was used. Most of the cats were fixed in formalin, but a few were examined fresh.

It is customary to regard some of the senescent changes in the disc as normal or maturation changes, and others as pathological or degenerative changes. In distinguishing maturation from degeneration we have followed quite closely the criteria which *Hansen* (1952) used for the dog. Maturation is essentially fibrous replacement of the nucleus pulposus, with perhaps a little chondroid tissue as well. A disc was regarded as degenerate if it showed any of the following features: 1. Rupture, either in the annulus or in a fibrotic nucleus. 2. Distinct distortion of the lamellae of the annulus, or of the whorls of a fibrous nucleus. 3. Generalized separation of the lamellae from each other. 4. Extensive conversion into chondroid material. 5. Calcification. 6. Brown or yellow discoloration.

For statistical analysis the chi-squared test was used to compare the incidence of degenerations in one region of the vertebral column as a whole with the incidence in another region as a whole. The standard error test for proportions was used to compare the incidence at one individual disc with the incidence at the other discs as a whole in the same region of the vertebral column.

RESULTS

In 100 adult cats 875 discs (33.6 per cent) out of 2,600 discs showed changes. Of these 223 (8.6 per cent) showed maturation and 652 (25.1 per cent) showed degeneration.

Maturation.

The normal nucleus pulposus of the young cat is slightly flocculent except for a narrow translucent zone round the periphery (Fig. 3). This normal cloudiness makes it difficult to distinguish the early stages of maturation in which there is a slight increase in opacity as in Fig. 4. Later the whole nucleus becomes completely opaque and definitely loses its gelatinous quality. Finally the nucleus is entirely replaced by fibrous whorls as in Fig. 5, possibly with a little chondroid material.

The distribution along the vertebral column of the discs with maturation is shown in Fig. 1. Their incidence in the cervical region (C2 to T1) was about the same as in the region between T10 and S1. There were 46 discs with maturation in the former and 82 in the latter region. Since the number of discs in these two regions is different, 6 and 11 respectively per cat, it is more informative to express the incidence as the mean number of discs with maturation for each disc of the region; the mean figures then are 7.7 and 7.5 for these two regions. In the region from T1 to T10 (9 discs), however, there were 95 discs with maturation or a mean of 10.6 per disc; statistically this incidence is significantly higher ($P = 0.01$) than the incidence in the other two regions. In the cervical region and region T1 to T10 no individual disc stood out as having an incidence significantly different from the other discs in its region. However, the incidences at T10-11 and at L5-6 and L6-7 were significantly higher (in all three instances $P = 0.02$) than the incidence in

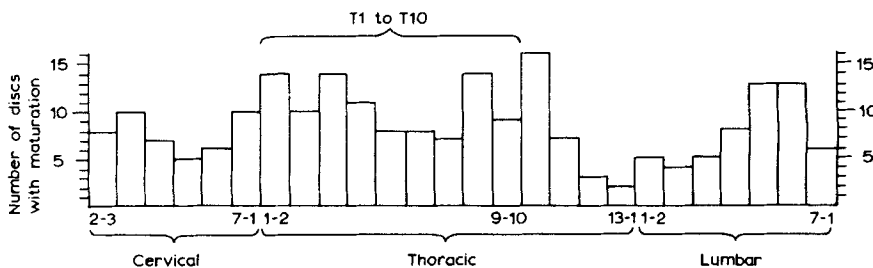


Fig. 1.

Distribution along the vertebral column of the 223 discs with maturation, found in 100 adult cats.

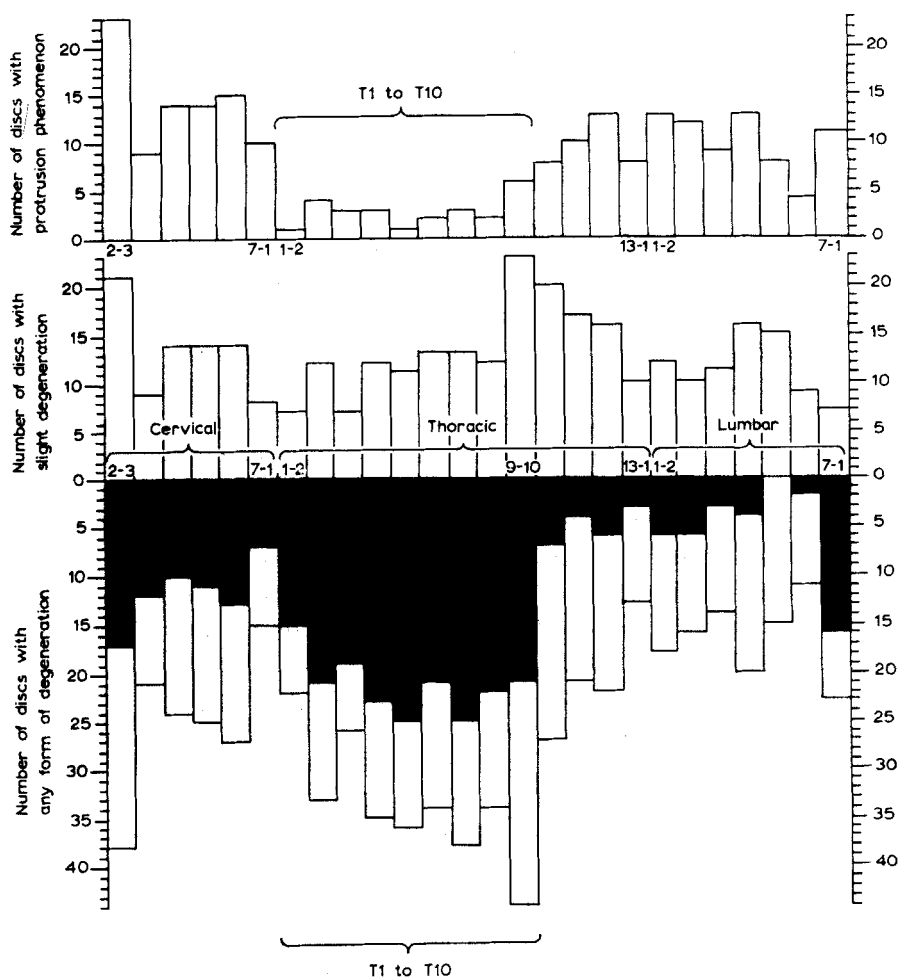


Fig. 2.

Distribution along the vertebral column of discs with protrusion phenomenon, slight degeneration, and all forms of degeneration, in the same 100 adult cats as in Fig. 1. *Top histogram:* distribution of the 219 discs with the "protrusion phenomenon", i.e. discs showing either dorsal protrusion, or ventral protrusion, or radial splits (no disc being counted twice). *Middle histogram:* distribution of the 333 discs with slight degeneration. *Bottom histogram:* distribution of the 652 discs with any form of degeneration. The black part shows the distribution of the 319 discs with the severe forms of degeneration (i.e. advanced degeneration, very advanced degeneration, partial destruction, total destruction, or ankylosis). The white part shows slight degenerations only, as in the middle histogram.

the rest of the discs between T10 and S1; it is therefore reasonable to accept the high incidence at L5-6, 6-7, as a genuine peak.

Degeneration.

The distribution along the vertebral column of the 652 degenerate discs is shown in the bottom histogram in Fig. 2 and is summarized in Table 1. Degenerate discs were massed in the 9 discs between T1 and T10. Statistically, the incidence was significantly higher in the region between T1 and T10 than in the cervical region ($P = 0.01$), and significantly higher in the cervical than in the region between T10 and S1 ($P = 0.001$).

TABLE 1

To show the relative incidence of the various degenerations in the three regions of the vertebral column in 100 adult cats.

	Slight degeneration No. of discs	Advanced degeneration No. of discs	Very advanced degeneration No. of discs	Partial destruction No. of discs	Total destruction No. of discs	Ankylosis No. of discs	Grand totals
Cervical region C2-T1 (6 discs)	80	35	10	8	13	4	150
Region T1-T10 (9 discs)	110	88	51	33	20	0	302
Region T10-S1 (11 discs)	143	35	13	8	0	1	200
Totals	333	158	74	49	33	5	652

Within the cervical region there was a very high incidence at the first disc, C2-3, and a low one at the last one, C7-T1. These two incidences were significantly different from the incidence at the other 4 cervical discs together; in the former $P = 0.01$ and in the latter $P = 0.02$. Throughout the region T1 to T10 the incidence was fairly even, except again at the first and the last discs of this region. The incidence at these two discs differed significantly from the incidence at the other 7 taken as a whole, the incidence at T1-2 being lower ($P = 0.01$) and that at T9-10 being higher ($P = 0.05$). In the region from T10-S1 the first disc once again stood out, and so did the last but one; the incidence at T10-11 was significantly higher and that at L6-7 was significantly lower (in both instances $P = 0.05$) compared with the other 9 discs taken as a whole.

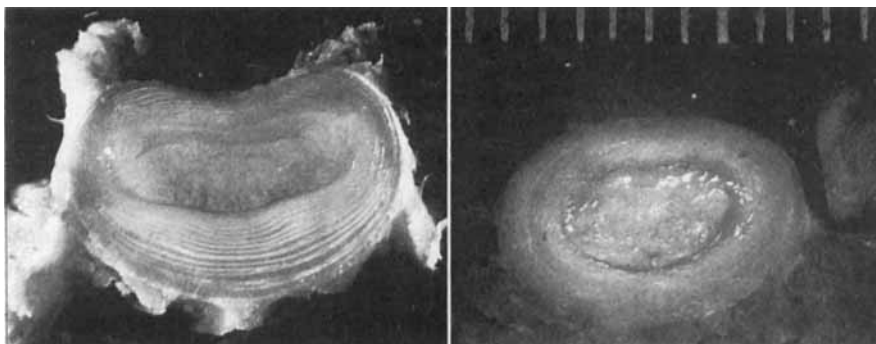


Fig. 3.

Figs. 3 and 4.

Fig. 4.

Fig. 3. Normal mid-lumbar disc of cat. The top of the page is dorsal (posterior) in position in all the figures.

Fig. 4. Early maturation of cervical disc of cat. Nucleus slightly opaque but still gelatinous. Scale in mm.

Six main classes of degeneration were distinguished as follows:

1. *Slight degeneration.* This term covered a number of minor degenerations. Three varieties which were relatively easy to recognize were minor distortions, small ruptures, and slight loosening and separation, of the lamellae of the annulus or of the whorls of a fibrotic nucleus pulposus; these changes were either local or generalized within a disc. When they were local the rest of the disc was often macroscopically normal. Thus, it was quite common to find slight degenerations in the annulus with an apparently normal nucleus, and vice versa. Radial splits (partial ruptures) and small protrusions leading from radial splits were classified as slight degenerations. Fig. 6 shows an example of slight distortion on the left and the right sides of the disc at about the junction of the regions of the annulus and the fibrotic nucleus. Less distinct varieties were chondrification of the nucleus (see below), homogenisation of parts of the annulus, and swelling of the lamellae. Calcification was also seen.

Including all varieties, slight degeneration was found in 333 discs (51.1 per cent of all degenerate discs); the details of their distribution along the vertebral column can be seen in the middle histogram of Fig. 2. The over-all incidence was much the same in the cervical region, in the region between T1 and T10, and in the region between T10 and S1, the mean incidences per disc in each region being 13.3, 12.2, and 13.0 respectively. Within the cervical region there was a high incidence

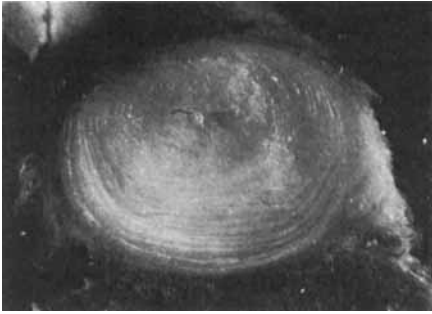
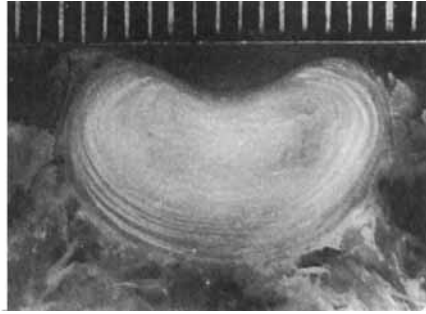
*Fig. 5.**Fig. 6.**Figs. 5 and 6.*

Fig. 5. Full maturation of cervical disc of cat. Nucleus replaced by fibrous whorls.
Fig. 6. Slight degeneration in mid-lumbar disc of cat. Slight distortion of lamellae on right and left sides at about the junction of annulus and fibrous nucleus. Scale in mm.

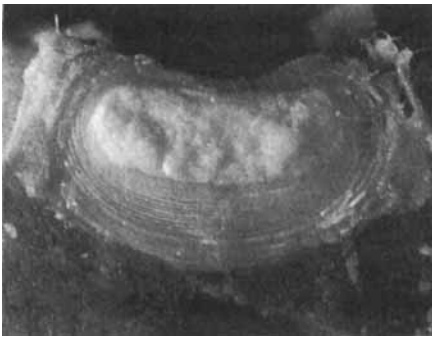
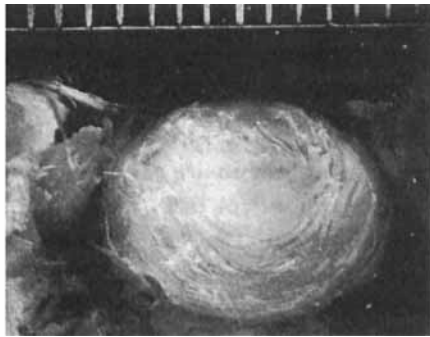
*Fig. 7.**Fig. 8.**Figs. 7 and 8.*

Fig. 7. Calcification of whole nucleus in late lumbar disc of cat. Calcified material dry, crumbly, and white.
Fig. 8. Advanced degeneration in cervical disc of cat. Generalized disruption and loosening of lamellae. Scale in mm.

at the first disc and a tendency for a low one at the last disc; the former was significant ($P = 0.05$) but the latter was not. In the region T1 to T10 there was a tendency for a low incidence at the first disc, T1-2, and there was a high incidence at the last, T9-10, the latter being significant ($P = 0.05$). In the region T10 to S1 there was a tendency for a high incidence in the cranial part, especially at the first disc T10-11, and a

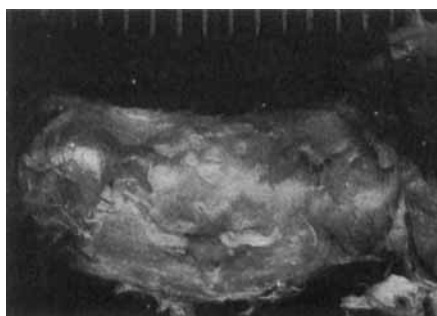


Fig. 9.

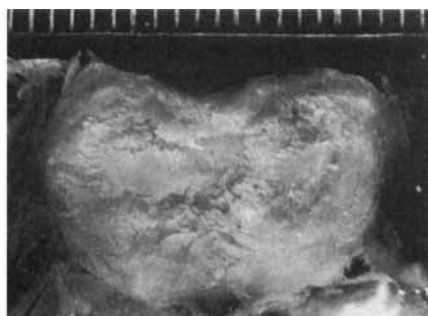


Fig. 10.

Figs. 9 and 10.

Fig. 9. Very advanced degeneration in mid-thoracic disc of cat. Original architecture lost. Ruptured lamellae everywhere. Scale in mm.

Fig. 10. Partial destruction of lumbar disc of cat. Disc reduced to shattered remnants, with areas of bone exposed. Scale in mm.

low incidence at the caudal end, especially at L7-S1; but none of these was statistically significant.

Calcification accounted for only 14 (4.2 per cent) of the 333 discs with slight degenerations. It appeared as a dry white crumbly material and was found in large areas of the annulus or nucleus as in Fig. 7. Since no chemical tests were made it is possible that this material was not in fact calcified.

2. *Advanced degeneration.* The disc showed either generalized changes everywhere, or very severe local changes. The former consisted firstly of disruption, or severe loosening and separation, of the lamellae; the example in Fig. 8 shows some disruption and much separation. Secondly the generalized changes sometimes consisted of chondrification; the large majority of the disc was then composed of a hard homogeneous cartilaginous material. Some discs combined chondrification with disruption and separation of lamellae.

The localized changes were very severe. For example a disc of which about one third had become a disorganized mass (the sort of change affecting the whole of the disc in Fig. 9) was classified as advanced degeneration; this could affect either the nucleus pulposus or annulus, or parts of both, but in addition the rest of the disc was almost always at least slightly degenerate. A number of severe protrusions were included in this category.

A total of 158 discs (24.2 per cent of all degenerate discs) were af-

ected by advanced degeneration, most of them being in the region between T1 and T10 (see Table 1).

3. *Very advanced degeneration.* The disc was absolutely chaotic, few or no signs of its original architecture remaining anywhere. Many lamellae were ruptured with their stumps sticking up in confusion (Fig. 9). Protrusions were sometimes present. Seventy-four discs (11.3 per cent of all degenerate discs) were in this condition (Table 1), the great majority of them being in the region between T1 and T10.

4. *Partial destruction.* Small areas of the discs, mainly in the central parts, had disappeared so that here and there bone was touching bone (Fig. 10). The rest of the disc was drastically disrupted, the two vertebrae being held together only by weak remnants of disc. Sometimes these remnants formed protrusions. Of the 49 discs which were so affected (Table 1), the great majority were in the region between T1 and T10.

5. *Total destruction.* Most of the disc had disappeared so that bone was in contact with bone over large areas. Remnants of the disc persisted round the edge, but these were totally disorganized; sometimes they formed protrusions. The two vertebrae were held together only by the most fragile fragments of disc tissue. Thirty-three discs had reached this stage. These were evenly distributed between the cervical region and the region between T1 and T10 (Table 1). Not one was found between T10 and S1.

6. *Ankylosis.* Ankylosis of two adjacent vertebral epiphyses may be part of the phenomenon of spondylitis rather than of disc degeneration; when it occurred the disc was invariably totally destroyed. Anyway it was rarely found, only 5 discs being so affected. All but one were in the neck (Table 1).

The severe degenerations considered as a whole.

The distribution along the vertebral column of all the five severe forms of degeneration together (advanced degeneration, very advanced degeneration, partial destruction, total destruction, and ankylosis) is shown as the black part of the bottom histogram in Fig. 2. A total of 319 discs had these degenerations, *i.e.* 48.9 per cent of all discs with degenerations. The majority (60.2 per cent or a mean of 21.3 per disc) were massed in the region between T1 and T10. Most of the rest were in the cervical region (a mean of 11.7 per disc), the region between T10 and S1 being relatively lightly affected (a mean of 5.2 per disc). Stati-

stically, the difference in incidence between the region T1 to T10 and the cervical region, and between the cervical region and the region between T10 and S1, was highly significant (in both instances $P = 0.001$). Particularly striking was the abruptness of the rise in incidence at the cranial end of the region T1 to T10, and of the fall at the caudal end of it.

Within the cervical region the incidence tended to be high at the first disc and low at the last one, but these differences were not significant. Within the region T1 to T10 the incidence was relatively low at the first disc but not significantly so, and thereafter was consistently high. Within the region T10 to S1 the last disc stood out with a remarkably high incidence ($P = 0.01$).

Chondrification.

This change was observed in discs which were classified as slightly or severely degenerate. It has not been classed as a separate entity for the reason that chondroid tissue cannot reliably be distinguished from fibrotic tissue with the naked eye. Nevertheless, the tissue identified macroscopically as chondroid was found histologically to consist mainly of dense fibro-cartilage. Although this figure is almost certainly too low, 123 discs (18.9 per cent of all degenerate discs) were recorded as showing chondrification. The great majority of these (80.5 per cent) lay in the region T1 to T10; there were very few in the cervical region (4.1 per cent), and rather more in the region T10 to S1 (15.4 per cent).

Discolouration.

Sixty-seven discs had dark-red or dark-brown discolourations which were either focal or widespread; 43 of these discs also had severe degeneration or protrusions, but only in 3 were these protrusions perforated. A light yellow discolouration, bright and distinct, affected 27 discs; nearly half of these discs showed only maturation or slight degeneration.

Relative severity of degenerations in the dorsal and ventral parts of the disc.

No evidence was found that any of the general degenerations described above affected the dorsal more than the ventral regions of the disc.

Relationship between changes in the discs and age.

In the 60 cats of known age the earliest changes to be found were in 2 of the 10 juvenile cats between 1 and 2 years of age. One of these cats had one disc showing maturation; the other had a single disc showing slight degeneration, the nucleus being completely fibrotic and having a large area of dark-brown discolouration. Both of these discs were in the region T1 to T10.

The cats in the age groups of 2 to 6 years old and 7 to 10 years old showed a tendency for a progressive increase with age in the incidence of maturation and degeneration; but these changes were only slight in degree, so that in the 7 to 10 group 88 per cent of the discs were still normal, while only about 7 per cent were degenerate and 5 per cent showed maturation.

In the next age group, 11 to 14 years old, there was a sharp acceleration in maturation and degeneration. Only about 50 per cent of the discs were still normal and about 30 per cent were degenerate. This acceleration continued still further in the senile group. By this time only 23 per cent of the discs were still normal, and a greater number than this (38 per cent) were affected by severe degenerations; over half the discs (61 per cent) had suffered some degree of degeneration. Nevertheless, even in this senile group every cat had one or several discs which apparently were still perfectly normal; even in the region T1 to T10 apparently normal discs were found sporadically interrupting sequences of grossly degenerate discs.

These changes occurred much more rapidly in the 9 discs between T1 and T10 than in the other two regions. The three regions changed at much the same rate up to and including the 2 to 6 year group (Table 2). But after that the discs in the region T1 to T10 began to change faster than those in cervical region and the region between T10 and S1; the latter two regions continued at roughly similar rates. Thus in the 7 to 10 years group about 80 per cent of the discs in the region T1 to T10 were normal and 5 per cent were severely degenerate; in the other two regions about 90 per cent were normal and only 1 per cent severely degenerate. In the 11 to 14 years group only 36 per cent of the discs in the region T1 to T10 were normal and 24 per cent were severely degenerate; in the other two regions about 60 per cent were normal and only about 7 per cent were severely degenerate. In the senile group, 15 to 20 years old, only 11 per cent of discs in the region T1 to T10 were still normal, and 64 per cent were severely degenerate. The other two

TABLE 2
To show the percentage of normal, mature, slightly degenerate, severely degenerate (all five forms together) discs in the three regions of the vertebral column in the 60 cats of known age.

	Cervical region. C2 to T1				Region T1 to T10				Region T10 to S1			
	Normal discs %	Mature discs %	Discs with slight degeneration %	Discs with severe degeneration %	Normal discs %	Mature discs %	Discs with slight degeneration %	Discs with severe degeneration %	Normal discs %	Mature discs %	Discs with slight degeneration %	Discs with severe degeneration %
10 Juvenile cats (1-2 years old) .	100				97.8	1.1	1.1		100			
10 Young cats (2-6 years old) .	96.7		3.3		95.5	1.1	2.2	1.1	89.1		10.9	
16 Early middle-aged cats (7-10 years old)	88.5	4.2	6.3	1.0	79.9	11.8	3.5	4.8	93.8	1.1	4.0	1.1
11 Late middle-aged cats (11-14 years old)	59.1	18.2	16.6	6.1	36.4	18.2	21.2	24.2	60.3	18.2	14.9	6.6
13 Senile cats (15-20 years old)	24.4	5.1	28.2	42.3	11.1	11.1	13.7	64.1	32.8	25.2	28.7	13.3

regions had now parted company through a sudden acceleration of degeneration in the cervical region in which only about one quarter of the discs were still normal, and nearly half (42 per cent) were severely degenerate: in contrast to this, in the region between T10 and S1 one third of the discs were still normal and only 13 per cent were severely degenerate.

The regular progression of these changes was interrupted at one point, *i.e.* in the region T10 to S1 of the young cats (2 to 6 years old). Here Table 2 shows 10.9 per cent degenerate discs, which is more than in the other two regions at this stage. This is due to the fact that, of the total of 14 calcified discs which were observed, 10 occurred in cats of this age group and in this region; no calcified discs were found in cats over 10 years old.

Relationship between degeneration and protrusion.

Protrusions (both dorsal and ventral) were found in combination with all the various types of degeneration described above. Thus, of the 333 discs which had undergone slight degeneration 87 (26 per cent) had protrusions; of the 158 discs with advanced degeneration 45 (28 per cent) had protrusions; of the 74 discs with very advanced degeneration 15 (20 per cent) had protrusions; and of the 87 discs with partial destruction, total destruction, or ankylosis, 29 (33 per cent) had protrusions. The distribution of radial splits among the various stages of degeneration was quite different, since the great majority (37 out of 43) were found in discs which were only slightly degenerate.

Fig. 2 enables the distribution of degenerations along the vertebral column to be compared with that of protrusions. The top histogram is the sum of all dorsal and ventral protrusions and all radial splits (no disc being counted twice); it therefore represents what may be called the "protrusion phenomenon". Altogether 219 discs showed the protrusion phenomenon; these comprised 127 discs with dorsal protrusions, 41 with ventral protrusions, 8 with both dorsal and ventral protrusions and 43 with radial splits. These are the protrusions and radial splits reported earlier (*King & Smith, 1960a, b*).

In the cervical region the distribution of protrusions agreed fairly closely with that of degenerations, especially of slight degenerations, but there was no agreement in the other regions of the vertebral column.

DISCUSSION

Degenerative changes.

A large variety of degenerations has been seen, ranging from slight local ruptures of lamellae to almost complete disintegration of the whole disc. These were arbitrarily grouped into six main classes of degeneration; slight degeneration, advanced degeneration, very advanced degeneration, partial destruction, total destruction of the disc, and ankylosis. The severest of these degenerations appear to correspond with *Hansen's* (1959) osteochondrosis vertebrae.

From their appearance and relative incidence, we believe that these six degenerations are really a sequence of changes which begins locally and mildly within the disc, and ends by involving the whole disc even to the point of destruction. Some such relationship was suspected by *Hansen* (1959) in his discussion of the cause of osteochondrosis vertebrae, though he was unable to rule out the possibility that the degeneration of the disc arose primarily from changes in the vertebrae. His difficulty here arises from the destruction of the cartilage plate and the osteolysis and osteosclerosis of the vertebral epiphyseal surface, which accompany the very severe degeneration of the disc. We suggest that these changes in the cartilage and bone are likely to be secondary to the disintegration of the disc, arising from the collision of the adjacent vertebrae.

Some of the degenerations observed failed to fit into the concept of this sequence, notably chondrification, discolouration, and calcification. Chondrification was the most difficult of these, partly because it was hard to distinguish it macroscopically from fibrosis; nevertheless, it was obviously quite a common change.

The dark-red and dark-brown discolourations looked as though they could have originated from blood. *Hansen* (1952, p. 54) found similar discolourations in the dog, complete with blood pigments (pp. 89, 111), but only in discs which had completely perforated protrusions or had been surgically fenestrated. In our cats, however, only 3 of the 67 affected discs had perforated protrusions and none had been fenestrated. Nevertheless, most of these discs were severely disorganized and may have contained damaged granulation tissue. Alternatively, these discolourations may have come from some unknown pigment, (for review see *Hansen*, 1952, p. 91, and *Hansen*, 1959). Of the discs affected with yellow discolourations many were only mildly degenerate or had undergone nothing more drastic than maturation, so it is difficult to see where blood could have come from. *Hansen* (1952, p. 54) saw yellow-

grey discolourations in the dog, but these were in perforated discs.

Calcification, or apparent calcification, was very rare; it was confined to cats younger than 10 years old, which suggested that it was not a typical senile change but part of some different process. In contrast, calcified discs were present in about 50 per cent of dogs of the chondrodystrophoid breeds over 2 years old, though rarely in other breeds (*Hansen*, 1952, pp. 63–65), and in about 75 per cent of humans over 30 years old (*Rathcke*, 1932).

Distribution of degenerations along the vertebral column.

A conspicuous feature of the distribution of degenerations has been the consistent severity of the changes in the nine discs from T1 to T10. Maturation and degeneration as a whole, and particularly the severe forms of degeneration, were massed within these nine discs. Moreover, these changes evidently occurred here much earlier (in the animal's life) and faster than elsewhere in the vertebral column. All this justifies the segregation of these nine discs in this species into a clear-cut group. As for the rest of the vertebral column, the cervical region showed more degeneration than the region from T10 to S1. A few individual discs stood out as being either specially susceptible or unsusceptible to degeneration. If all forms of degeneration are considered together the first disc of all, C2–3, had nearly the highest incidence throughout the whole vertebral column, while the last disc of all, L7–S1, had an exceptionally high incidence of severe degeneration. On the other hand the disc L6–7 was the least susceptible disc throughout the vertebral column; this observation is rendered more remarkable by the fact that this disc also had no dorsal protrusions (*King & Smith*, 1960b). *Hansen's* (1959) attractive concept of "the disc organ" visualized all the discs of the vertebral column as a whole organ in which changes take place rather uniformly. Our impression of the cat leads us to suggest essentially the opposite principle, namely that there is a different susceptibility to degeneration in certain well-defined regions of the vertebral column and perhaps even of certain individual discs.

It is interesting to compare the regional distribution of degeneration of the disc in the cat with the regional distribution of degeneration in other species. Apparently the only comparable surveys carried out in other species (excluding surveys of protrusions) are that of calcification in the human disc by *Rathcke* (1932) and calcification in the canine disc by *Hansen* (1952). One notable similarity emerges; as in the cat,

the thoracic region is much more affected than any other part of the vertebral column. Thus by far the greatest incidence of calcification occurred in the nine discs from T2 to T11 in *Rathcke's* material and in the 13 discs from T1 to L1 in *Hansen's*. It is a fascinating question; why should the discs in the thoracic region, specially in the part cranial to the 11th thoracic vertebra, be so susceptible to degeneration?

No evidence was found that the dorsal part of the disc was any more affected by degeneration than the ventral part, unlike the dog (*Hansen*, 1952, p. 65) and man (according to widely accepted opinions). However, it is possible that histological examination would have disclosed a preferential degeneration in the dorsal annulus of the cat also.

Degeneration and protrusion.

In considering the relationship between protrusion and the various classes of degeneration we have taken dorsal and ventral protrusions together as a whole. In an earlier paper (*King & Smith*, 1960a) reasons have been given for regarding radial splits as precursors of these protrusions; therefore, radial splits also have been added to dorsal and ventral protrusions. We have called this combination of splits and true protrusions "the protrusion phenomenon".

Do protrusions arise at any and all stages of degeneration or do they arise at only one stage of degeneration? If protrusions arise spontaneously at all stages of degeneration they should accumulate progressively in the more severe stages of degeneration (assuming that the sequence of degeneration does occur); *i.e.* there should be a progressively larger proportion of protrusions in the more severe degenerations. On the other hand if protrusions arise only, for example, at the stage of slight degeneration, then in each stage of degeneration the proportion of discs with protrusion should remain constant (again assuming the sequence to occur).

The proportion of protrusions actually observed seemed to be approximately constant in each stage of degeneration. Radial splits on the other hand were nearly confined to discs at the stage of slight degeneration. These data fit the hypothesis that the protrusion phenomenon originates mainly at the stage of slight degeneration.

The presence of slight degeneration certainly cannot be the only factor which induces protrusion. A very large proportion of discs in the region between T1 and T10 must have gone through the stage of slight degeneration, but all forms of the protrusion phenomenon were rare in

that region. Similarly the two discs T10–11 and T11–12 had a very high incidence of slight degeneration, but a very low incidence of the protrusion phenomenon. Only in the cervical region did the incidence of slight degeneration closely fit the incidence of the protrusion phenomenon.

Age changes.

The onset of widespread degeneration in the cat begins essentially in late middle-age (in the age group 10 to 14 years). In senile cats between 15 and 20 years old the process is further accelerated. Even the oldest cat, however, always had at least one and usually several discs which were still normal. This was particularly remarkable in the region from T1 to T10 where apparently normal discs were found scattered among sequences of grossly degenerate discs. This again leads us to question the concept of the "disc organ". The onset in late middle-age is in contrast to the protrusion phenomenon which in the cat is essentially a feature of senility; dorsal protrusions as well as radial splits and ventral protrusions all occur mainly in cats 14 years old or more (*King & Smith, 1960a, c*). In non-chondrodystrophoid breeds of dog *Hansen (1952, p. 65)* found macroscopic degenerations in "isolated" dogs under 7 years old; he further noted that "even in the age group above 7 years they do not amount to a considerable figure", and from this it appears that disc degeneration must be a good deal less common in old dogs (non-chondrodystrophoid) than in old cats.

S U M M A R Y

1. The macroscopic changes in the intervertebral discs (except coccygeal) of the cat have been surveyed.
2. Maturation (fibrous replacement of the nucleus pulposus) was found in 33 per cent of the discs.
3. Degeneration was found in 25 per cent of the discs.
4. Six main forms of degeneration were distinguished ranging from slight rupture of lamellae to total destruction of the disc with ankylosis.
5. The appearance and incidence of these forms of degeneration are interpreted to indicate that they constitute a progressive sequence of changes.
6. Maturation and degeneration increased progressively with age but remained uncommon in young cats. In the age group of 11 to 14 years the incidence and severity of degeneration sharply increased. Therefore,

in the cat the onset of extensive degeneration is essentially in late middle-age, in contrast to protrusion which occurs essentially in senility in this species.

7. Degenerations occurred more frequently, more severely, and earlier, in the nine discs from T1 to T10 than elsewhere in the vertebral column. The region T11 to S1 was the least affected. It is suggested that the discs from T1 to T10 form a distinct group, but no anatomical explanation of this can yet be offered.

8. Protrusions were found equally commonly in combination with all the main forms of degeneration. Radial splits, which are believed to be precursors of protrusions, were virtually confined to discs with only slight degeneration. These relationships suggest that protrusions begin at the stage of slight degeneration.

R E S U M E

1. Une étude a été faite des changements macroscopiques dans les disques intervertébraux (à l'exception des disques caudaux) dans le chat.

2. Dans 35 pour cent des disques une maturation (remplacement fibreux du nucleus pulposus) fut constatée.

3. Dans 25 pour cent des disques une dégénérescence fut constatée.

4. On distingua 6 formes principales de dégénérescence, depuis une rupture légère des lamelles jusqu'à la destruction totale des disques accompagnée d'une ankylose.

5. L'aspect et la fréquence de ces formes de dégénérescence indiqueraient, d'après l'interprétation donnée, une série progressive de transformations.

6. La maturation et la dégénérescence augmentèrent par degrés avec l'âge, mais ne se manifestèrent que rarement chez les jeunes chats. Dans le groupe âgé de 11 à 14 ans, la fréquence et la gravité de la dégénérescence augmentèrent de façon marquée. Une dégénérescence extensive se manifeste donc surtout sur le déclin de la vie et fait contraste avec la protrusion, qui, dans cette espèce, se manifeste surtout dans la sénilité.

7. Une dégénérescence se manifesta plus souvent, plus tôt et avec plus de sévérité dans les 9 disques de T1 à T10 qu'ailleurs dans la colonne vertébrale. La région la moins affectée fut de T11 à S1. Il est proposé que la région de T1 à T10 constitue un groupe uni, bien que l'on ne puisse encore fournir aucune explication d'ordre anatomique.

8. La fréquence des protrusions liées à toutes les formes principales de dégénérescence fut constante. Les fissures radiales, que l'on croit être précurseurs aux protrusions, se limitèrent presque entièrement aux seuls disques atteints d'une dégénérescence légère. Ces rapports suggèrent que les protrusions se montrent d'abord à un degré de dégénérescence légère.

ZUSAMMENFASSUNG

1. Es wurde eine Übersicht über die Veränderungen bei den Zwischenwirbelscheiben der Katzen (mit Ausnahme der Schwanzwirbel) durchgeführt.

2. Maturation (fibröse Umbildung des nucleus pulposus) wurde in 33 Prozent der Scheiben gefunden.

3. Degeneration wurde in 25 Prozent der Scheiben gefunden.

4. Es wurden 6 verschiedene Degenerationsformen unterschieden angefangen, von einem leichten Lamellenbruch bis zur vollständigen Zerstörung der Scheibe durch Ankylosis.

5. Das Aussehen und die Häufigkeit dieser Degenerationsformen wird als Hinweis auf eine fortschreitende Folge von Veränderungen angesehen.

6. Maturation und Degeneration nahmen mit fortschreitendem Alter zu, fanden sich jedoch bei jungen Katzen selten. Die Altersgruppe von 11–14 Jahren zeigte einen scharfen Anstieg in der Häufigkeit und in der Schwere der Degeneration. Daraus ergibt sich, dass bei Katzen eine ausgedehnte Degeneration im wesentlichen im späten Mittelalter einsetzt, im Gegensatz zu einer Protrusion, die meistens bei diesen Tieren erst im senilen Alter auftritt.

7. In den neun Scheiben, T1–T10, traten Degenerationen häufiger und früher auf und waren schwerwiegender als anderswo in der Wirbelsäule. Die Gegend von T1–T10 war am wenigsten betroffen. Es besteht Grund zur Annahme, dass die Scheiben von T1–T10 eine besondere Gruppe darstellen; eine anatomische Erklärung hierfür kann jedoch bis jetzt nicht in Vorschlag gebracht werden.

8. Protrusionen fanden sich auch ebenso häufig in Verbindung mit allen wesentlichen Degenerationsformen. Radiale Risse, die als Vorläufer von Protrusionen angesehen werden, waren fast ausschliesslich auf Scheiben mit nur leichten Degenerationserscheinungen beschränkt. Diese Zusammenhänge lassen vermuten, dass Protrusionen im Stadium der leichten Degeneration ihrer Anfang nehmen.

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