"SENECTAS insanilibus morbus est". This axiom of Seneca, though 2000 years old, could well be said to have dominated medical thought until the twenties of the present century. Even now, although gerontology has existed more than 30 years as a separate science and the notion "the physiological old age" is in general use, text-books of anatomy, histology and physiology lack special treatment of the normal senescent organs and bones. Oddly enough we find much more information on bone ageing in text-books of pathology and in other works dealing with the clinical and pathological picture of bone affections.

The literature on the ageing and aged vertebral column is very scanty, particularly that which deals with the radiological aspect of these problems. The only work on the ageing of the vertebral column, with special reference to the radiological method, is that of Junghanns. In 1931 he summarised all the existing knowledge on this subject and postulated, though very cautiously, the possibility of normal (physiological) bone ageing in the vertebral column. His suggestions were apparently not favourably received since a very instructive book written by his teacher S. Schmorl, The Vertebral Column in Health and Disease, published in 1932, does not deal with physiological bone ageing. In the last edition of this book (1953) there are chapters on "presenile" and "senile" osteoporosis in which these phenomena are treated as quite definite nosological entities with obligatory clinical symptoms. There are also several statements on the preponderance in old age of several hypertrophic signs but always in connection with spondylitis or spondylosis deformans. Though Junghanns was rather vague in his definitions of physiological bone changes in old age, he was the first to suggest their existence. He also pointed out that atrophy and hypertrophy may co-exist in ageing skeletons.

Many radiological works on atrophic changes in the vertebral column were published prior to 1941. These changes were, however, treated by all authors as some kind of disease, to be encountered more frequently in old age (see publications of Baron and Barsony, 1927; Goehcke, 1931; Rokhline and Roubasheva, 1936; Polgar, 1937; and others).

The question of normal ageing bone atrophy was brought into discussion again in 1941 by Black, Chormley and Camp. They pointed out that "senile osteoporosis" as described in the literature "has nothing to do with the usual senile osteoporosis observed by us, being quite a definite nosological entity with typical clinical symptoms (pains, stiffness, change of stature, frequently compression fractures)".

Burrows and Graham were even more categorical. In 1945 they emphasised that the term "senile osteoporosis" is very misleading because a real disease which is understood under this term happens to young people and has a definite clinical picture. In the opinion of these authors the gross pathology of senile osteoporosis and osteomalacia is
very similar. In this connection it should be mentioned that the term "senile osteomalacia" instead of "senile osteoporosis" was proposed by Ribbert as early as 1880; it was not universally accepted, however, since some authors, particularly Pommer and Schmorl, considered these to be different diseases.

The possibility of physiological osteoporosis was pointed out also by Albright (1947), Bick (1952), Bick and Coppel (1952) and Cobb (1952). The gross pathological and histological study of senescent vertebrae by the latter two authors is especially instructive. They stated definitely:

It is evident that the appearance of osteophytosis in an aged spine cannot be passed off simply as arthritis nor can the appearance of a usual degree of spotty lysis in a senescent vertebra be classified as pathological osteoporosis.

This quotation shows that the authors considered both atrophy and hypertrophy to be, to some extent, typical of the ageing vertebrae. Similar opinions have been expressed by Cobb (see above) and more recently by the present writer (1954).

In this work there is no intention of reviewing the numerous literary data on the genesis of bone atrophy in general. For our purpose it would be sufficient to point out only a few works directly related to our theme. Of the many theories on this subject two are in current use. They may be designated: the hormono-cellular and the humoral.

The hormono-cellular hypothesis is due to the independent work of two authors, Pommer (1914) and Albright (1947). According to Pommer, old age osteoporosis is due to the decreased activity of osteoblasts failing to produce new osteoid tissue; osteolytic activity of osteoclasts, however, continues. Consequently the ageing bone loses its calcium. According to Albright the stimulation of activity of osteoblasts depends upon two hormones: N-hormone (one of adreno-cortical hormones) and sex-hormone (androgen in men and estrogen in women). This stimulation is kept in balance by the suppressing action of another adrenocortical hormone, S-hormone or sugar-hormone. In old age the secretion of both stimulating hormones becomes diminished whilst the secretion of S-hormone continues unabated. Consequently the calcium balance is upset. Although reasonably formulated, however, the hormono-cellular theory does not explain all the known facts of osteoporosis.

The humoral theory of bone atrophy was proposed by Kilian (quoted by Beck) and has been named by him halisteresis. Volkmann (1882) compares the process of bone resorption in halisteresis to maceration of bone with hydrochloric acid; the organic bone substance and cartilage with bone cells would then become an elastic fibrillar mass. Thus the halisteresis theory connotes atrophic absorption by a chemical process without obvious cellular action.

Some of the difficulties encountered by students of bone atrophy were realised as long ago as 1899 by M. Schmidt when he stated that of the few histological criteria in existence none can be regarded as absolute. The histological method cannot detect the most minute deviations in calcium content of bone since the method requires the total removal of calcium from the bone prior to examination.

The available data on hypertrophy of bone in old age and, in particular, on the spine are very controversial.

Confusion begins here with the terminology. As early as 1897 Beneke showed that there is no inflammatory origin in the deformative process of the spine and he proposed to call it "spondylasis" deformans instead of spondylitis deformans. In spite of his authority and the support given to this proposition by Pommer (1914), Junghans (1934), Comroe (1947), Babajantz (1948), Schmorl (1953) and others, "spondylitis deformans" continued to be used by the majority of authors. Some of them mention "spondylasis" without giving any explanation of this term (e.g. Brailsford, 1953). In English-speaking countries the term "degenerative osteoarthrosis" is in general use. As Dible (1950) rightly has pointed out, this term is also contradictory because "osteoarthrosis" refers to the effects on the bony parts of the joints, whereas the term "degenerative" pertains to the changes in the synovial and cartilaginous elements. Finally, another term, "hypertrophic arthritis", is used. According to this term every bone hypertrophy, even the most minute, is a sign of this disease. Lund followed this line of reasoning to its logical end and considered everyone over 50 years of age to be suffering from arthritis (1932).

The morphology (both gross and microscopical) of spondylosis deformans with special reference to the macroradiological method had been thoroughly worked out by 1942 in the authoritative essays of Schmorl (1953), Junghans (1931), Brailsford (1953), Schinz, Baensch, Friedl, Uelinger, Lehrbuch (1932), Lang (1939) and others. All these authors have, however, continued to consider hypertrophic changes of bones in general and of the vertebral column in particular as some kind of disease; everyone has looked upon hypertrophic changes in old age as some complication of the degenerative process in the intervertebral disc. And so far as the degeneration is concerned this process has never been considered normal or typical for the ageing
The Ageing Vertebral Column (Macro- and Historadiographical Study)

organism. All the above authors failed, however, to consider that a great many old people feel quite well and have no clinical symptoms of any disease: this, in spite of the fact that their bones as their other organs present some changes typical for their age.

An important work was published by Bennet, Waine and Bauer (1942). These authors examined bones and joints of persons of various age groups after accidental death and came to some far-reaching conclusions. They stated that:

Histologically the first evidence of peripheral elevation consisting of proliferating fibrous tissue was found in the articular margins and in specimen belonging to the late second decade, in which the developmental changes just outlined had taken place (p. 49).

And further:

With advancing years the periarticular margins increased progressively in prominence and irregularity and exhibited, in older age groups, well-defined lipping composed of metaplastic cartilage, hyaline cartilage and bone... It is apparent, therefore, that articular lipping is not a prerequisite for the diagnosis of degenerative joint disease.

Though this work was not concerned with all the problems of the morphology of ageing bones, it appears to be a turning point in our understanding of the development of hypertrophy in bone. Prior to this work every lipping was considered to be a sign of pathology. Conclusions of Bennet et al. (1942) so far as the spine is concerned were later confirmed by the works of Bick (1952) and Bick and Coppel (1952).

Thus, during the last two decades, many observations have been collected which enable us to conclude that the human skeleton with advancing years develops hypertrophic and atrophic changes which are no prerequisite of disease and which are typical for everyone in a given age group.

Up to the present no attempts have been made towards establishing a border-line between normal bone ageing and the beginning of pathology. Nor have there been any attempts made towards finding out the principal features of gross-anatomy, histology and radiology of normally ageing bones, particularly those of the vertebral column.

The literature on the subject lacks any data on the application of historadiography (microradiography) in the study of the ageing vertebral column, though the possibility of bone study using this method was pointed out by Lamarque (1936), Sievert (1936), Barclay (1947), Clark (1947), Engstroem (1949) and Mitchell (1951). The writer reported recently on some results achieved by this method in his studies on ageing bones.

Engstroem and Lindstroem (1951) have thoroughly described the application of fine-grained emulsions for historadiography. They have pointed out that commercially available plates permit the recording of images with a resolution as low as 1 μ with strong contrast. So far this resolution has proved to be adequate in this kind of bone research.

The only radiological study on bone changes in ageing animals known to the writer is that of Schmey (1915). This author has found atrophic changes in bones, and especially in the skulls of old dogs. He has also observed some hypertrophic changes in their bones and has proposed to name all such changes "osteodystrophia rareficans senilis".

Taking into consideration the data cited above, we have attempted to study the following problems:

1. To observe and analyse morphological changes in the ageing vertebral column of normal old persons by means of the macroradiographical and historiographic methods.
2. To find out some characteristics of the differentiation between normal and pathological ageing changes in the vertebral column.
3. To investigate changes in the vertebral column of ageing animals with the same radiological methods and to compare them with those found in humans.

We have chosen the macroradiographical method for the present study because it is intended to follow the ageing bone changes in their dynamic aspect. The radiological method is the only one in which we may attempt the study of the anatomy of a living being. We have also set ourselves the task of combining the macroradiographical investigation with the historiographical study of those specimens of aged bones that were available for this purpose; in particular specimens of human and canine aged vertebrae.

Material and methods

Seventy-five persons (50 men and 25 women) from homes for the aged and from private homes were used for this study. Age limits were from 40 to 94: from 40 to 49 (3), from 50 to 59 (3), from 60 to 69 (13), from 70 to 79 (23), from 80 to 89 (31), from 90 to 99 (2). Apparently healthy persons who were not under medical treatment were chosen. Three of these people gave a history of trauma and two had slight strokes. We did not take into consideration such complaints as casual pains which did not cause any considerable discomfort. In the male group 40 were manual (physical) workers (often up to 70 and over) and six belonged to white-collar professions. Of the female group 21 women were housewives, four were otherwise employed.

At least five radiographs were made of each lower thoracic and lumbo-sacral region: ventro-dorsal,
v.d. with maximum bending, latero-lateral, 1-1 with maximum flexion, 1-1 with maximum extension. Technique: erect position (only in few cases recumbent), Potter-Bucky, kV and mAs depending upon individual physiques. Additional radiographs were made in several cases of the upper thoracic and cervical vertebrae. Radiographs of the ageing vertebral column from the author's records and all the material on ageing bone research mentioned in his recent publication were also used for this study.

Dissected vertebral columns from 12 old dogs (9 to 15 years of age) were macroradiographed and historadiographed and the findings are discussed in this work.

Finally the results of some 600 historadiographs of bone at different ages, including those of the vertebral columns of humans and dogs, are discussed.

**Historadiography technique**

The indirect method of historadiography has been used. Radiography was performed by the Machlett diffraction tube A-2, tungsten anode, water-cooling system, beryllium window, 10–20 cm anode-film distance. Additional diaphragm was used in order to get a field of 21 cm diameter on 20 cm distance, 15–20 kV or less according to the thickness of bone section, 12–20 mA, 10–25 min exposure time. Eastman Microdol Developer or G-251, when Gevaert film was used.

548–GH and 548–O, 649–GH and 649–O Eastman Kodak stereoscopic plates were used; in several cases also Gevaert films with the Lipmann emulsion.

After the usual processing and drying, the resulting radiographs were fixed on slide glass with the emulsion side up and were studied under the ordinary microscope at magnification of ×100 to ×300. The grain of the emulsion was apparent above ×300. Research is in progress to produce an emulsion with a finer grain for higher magnifications.

There were some difficulties in cutting the undecalified bone. With the usual zig-saw and the so-called jewel blades it was not possible to get sections thinner than several millimetres. It was also difficult to get sections of equal thickness with the zig-saw. After previous embedding of bone in some plastic (we used the tissue embedding solution No. 4700 Randolf Co.) it was found possible to obtain with the zig-saw thinner and more uniform sections. And finally, using a polishing disc (through the courtesy of Dr. Belanger, Prof. of Histology, Ottawa University) single sections 15–20 μ in thickness were obtained.

A photometer was used only in a few cases for the evaluation of X-ray absorption in the vertebral column. The estimation of the calcium content in bone was done mostly with the naked eye.

**RESULTS**

Several typical changes have been observed in macroradiographs of the spine of all the people in our study over 50 to 55 years of age. The signs of these changes might be divided into two groups: atrophic (or osteoporotic) and hypertrophic (some authors call them "osteosclerotic" but we prefer the former term because osteosclerosis is not always accompanied by bone hypertrophy or is it the result of the latter).

**Atrophic (osteoporotic) changes**

In old age the bone of the vertebral column passes through the same changes as the other bones of our skeleton. Bone atrophy is no exception to this rule. In our research bone atrophy in the vertebral column is revealed by two signs: (a) a general decrease of X-ray absorption and (b) morphological changes.

The naked eye of an experienced radiologist is the best instrument both for the detection of bone atrophy and for the determination of its degree. The radiologist takes into consideration the extent of the blackness in the bone and the surrounding soft tissues; the thickness of the compact bone; the amount, direction and distribution of trabeculae; the presence of destructive changes, etc. For the appraisal of calcium content in macroradiographs of the spine the eye is even superior to the photometer. The photometric rating in these macro-radiographs would depend not only upon the absorption of X-rays in the vertebral column but also on such factors as the thickness of the body and the distance between the vertebral column and the film, kV, mAs, sample of photo-emulsion, concentration and composition of the developer, time of development, fixing, etc. The presence of so many factors influencing the radiograph of the vertebral column makes it difficult or even almost impossible to obtain the true photometrical rating of these radiographs. The photometry in this research was used for the control of the eye in the appraisal of calcium content in the macroradiographs of macerated vertebrae.

In another paper we intend to report on the application of photometry for the detection of slight bone atrophy in macroradiographs of the hand. In these macroradiographs the possible errors mentioned above may be minimised and standardisation is much more easily achieved than in radiographs of the vertebral column.

We found signs of bone atrophy in macroradiographs of the spine of persons over 50 to 55 years of age. In women it became apparent earlier than in men. This fact has been mentioned by many authors (Albright, 1947; Beck, 1925; Junghanns, 1934; Schmorl, 1953; Schmidt, 1931; Comroe, 1947; and others). This early bone atrophy in females has been named "postmenopausal osteoporosis" because it develops often at that time.

All radiographic signs of bone atrophy are known so we will not discuss them here. In X-ray absorption and morphology these signs are the same for the vertebral column as for other bones of the skeleton.

The exact determination of different stages in the
development of ageing bone atrophy would be possible only if we could compare radiographs of the same person made with the same technique in various decades of his lifetime. A period of time of 20 to 30 years would be necessary to make such a determination. We have to be content, therefore, to determine the different stages of bone atrophy by comparing radiographs made in different persons in various decades of their lives. Here again we are confronted with many new difficulties. Before comparing radiographs we are obliged to consider the sex, profession, and standard of living of the ageing persons concerned and to choose people of similar status. Such selection is far from easy as the number of ageing persons available for study is always limited. Even under these unfavourable circumstances we may approach the understanding of the development of atrophy in ageing bone provided we are cautious with our conclusions. Radiographs of the female vertebral column at 65 and 94 and the same of the male at 61 and 85 are presented here for comparison (Figs. 1 and 2). Bone atrophy is more apparent at the age of 94 and 85.

![Figure 1](image1.png)

**Fig. 1.** Routine antero-posterior films, erect position, females: (A) 65 years old; (B) 94 years old. Atrophic changes in B are well visible, especially in area of pedicles, which are only slightly outlined.

![Figure 2](image2.png)

**Fig. 2.** Comparable films of males: (A) 61 years old; (B) 85 years old. The same differences in X-ray absorption between A and B as in the case in Fig. 3 are clearly seen.

![Figure 3](image3.png)

**Fig. 3.** Difference in the width of intervertebral space between III and IV L. during flexion A and extension B in case of “Fisch Wirbel”.

![Figure 4](image4.png)

**Fig. 4.** Antero-posterior film of Fig. 3. Male, 76 years old. Extensive hypertrophic changes between III and IV L.
“Fisch Wirbel” which Junghanns considered to be a radiological sign of compression fracture resulting from “senile osteoporosis”. According to Junghanns, Polgar and others, this kind of atrophy is accompanied by definite clinical symptoms such as pains, restriction of function and so on. Our ageing men with “Fisch Wirbels” did not complain of any pains and the vertebrae in the area of this deformity preserved a considerable amplitude of movement (Figs. 3 and 4). Although these old men denied any injuries in their case histories, we are sure that some unobserved trauma had taken place previously; perhaps long before signs of atrophy appeared. In people of such low intellectual level as these two men, this trauma would probably have been regarded as “lumbago”, “rheumatism”, or some other disease. The intensive development of hypertrophic bone in the area of the trauma in one of these male subjects indicated that the vertebrae had been injured a long time ago. Junghanns has emphasised that for “senile osteoporosis” a bone (periostal) reaction is not typical. All evidence mentioned above shows that “Fisch Wirbel” even in the atrophic ageing spine is not necessarily a sign of “senile osteoporosis”. An important question immediately arises, whether to treat these men as normally or as pathologically ageing people? We prefer rather to consider them as normally ageing notwithstanding the presence of a definite deformity which might well lead one to classify them as pathological cases. From the clinical point of view they are now quite normal and that is the most important consideration.

Macroradiographs of the vertebral column in dogs from 9 to 15 years of age have shown that vertebral atrophy is present in all animals over ten years of age. This finding is in accordance with the work of Schmey previously mentioned. The general decrease of X-ray absorption in a dog’s spine was always accompanied by morphological changes such as thinning of the corticalis, emphasised trabecular structure of vertebral bodies and increased differentiation in X-ray absorption between compact and spongiose bone. These atrophic changes were always associated with the hypertrophic changes which will be discussed later.

In historadiographs of atrophic vertebrae we have found some peculiarities which cannot be explained on the basis of the hormono-cellular theory alone.

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**Fig. 5.**
Historadiograph of an atrophic trabecula, ×200. In addition to the typical decalcification on the periphery of bone caused by osteoclasts, the enlargement of intraossal lacunae is clearly visible.

**Fig. 6.**
Historadiograph of an atrophic bone, ×200. Enlarged intraossal lacunae are shown. In the upper part of the picture several fused lacunae are visible.

Along with the typical destructive process on the periphery of bone trabeculae, caused by osteoclasts, there is enlargement of intraossal lacunae and possibly also of the Volkmann canals (it is necessary to mention that no osteoclasts have been found up to now in these bone elements). The enlarged intraossal lacunae have sometimes been fused into a bigger cavity. The same phenomenon was observed in the area of the Volkmann canals (Figs. 5 and 6). Such enlarged lacunae and cavities were especially numerous in the subchondral region. Sometimes we have seen the same dentations on the inner walls of intraossal lacunae and cavities as those developed on the periphery of bone trabeculae where osteolysis is carried on by osteoclasts. All these observations show that loss of calcium in the course of bone atrophy takes place not only via osteoclasts but also through halisteresis or through another, still
unknown, mechanism. A similar conclusion was reached by Marchand (1908) who stated that in "senile osteomalacia," he observed the disappearance of some bone trabeculae "with no giant cells present." Roessle (1913) has also noted the loss of biochemist and histologist. The role of "bone cells" (osteocytes) is quite obscure in the mechanism of osteolysis; the medium and the route through which calcium leaves the bone are also unknown. The historadiographical study of bone atrophy is similarly far from complete. Our results show, however, that in so far as the study of the morphological aspect of bone atrophy is concerned, historadiography opens new ways for investigation. Another likely use of historadiography is in the quantitative analysis of calcium content in atrophic bone; this has been pointed out already by Engstroem (1949) and is now under investigation.

The "broken" trabeculae were in no case observed in our historadiographs, though one of the vertebrae studied resembled very much the "Fisch Wirbel" already mentioned. In this vertebral body, as well as in others of normal configuration, the bone trabeculae were always straight and had a typical distribution.

In addition to the historadiographical picture typical of physiological ageing, changes have been seen in some bones which could not be explained by the loss of calcium due to atrophy alone. In such cases areas of destruction were found on the periphery of the bone. Inside the bone different cavities with irregular walls were observed. Some of these calcium in rickets which he could not explain by the cellular theory alone. Mere morphological findings cannot, of course, explain the manifold problem of aetiology of bone atrophy since there are many questions which can only be answered by the cavities were impregnated with calcium. Bone structure was not observed in this accumulation of calcium (Fig. 7). We consider this picture to be typical of some pathological process. It is quite possible that some healed or fresh inflammatory
process in bone presents such X-ray signs; but, of course, these conclusions can only be verified by specific studies.

According to Leriche and Policard (1928) calcium removed from the bone is not carried far away and it seems likely that this hypothesis is true for the described in the osteomalacic group of diseases; their presence, therefore, may be conclusive in a differential diagnosis of both kinds of atrophy. Radiographs from the author's files (reproduced in Figs. 10A and 10B) are good examples. Both radiographs show the vertebral column of females in their eighties. In A there is extensive calcification of the costal cartilages, together with atrophic and hypertrophic changes in the vertebral column, typical of this age. We consider this case to be quite normal. Radiograph B represents similar signs of ageing in the vertebrae but no calcification is visible outside the vertebral column. This is typical of "senile osteoporosis".

Historadiographs of the atrophic spine in old dogs present a picture similar to that observed in humans. In our material there were no historadiographs of canine vertebrae showing signs of pathological ageing.

**Hypertrophic signs**

There is general agreement in the literature that various spinal deformities occur most frequently in old age. Since the great majority of these deformities are caused by hypertrophic processes, we consider bone hypertrophy to be one of the typical signs of the ageing spine. This conclusion is confirmed by the curve shown in Table I (from Junghanns). According to this curve any spine will be affected by the deforming process after the seventh or eighth decade of life. After 40 years of age there are some deformities, i.e. hypertrophic changes in the vertebral column in 60 to 80 per cent of the population. Our observations are quite in agreement with these facts.

Radiographs show that the first sign of hypertrophy is an increase in size of the vertebral body due to enlargement of the apophyses (Fig. 11). If we compare the lumbar vertebrae of young adults of about 30 with those of persons over 45, the larger vertebral bodies are always found in the older group.
This observation shows that the vertebra continues to grow even after the period of post-natal development is completed. In the course of this growth the upper surfaces of both apophyses become uneven and less smooth than in the earlier years. This enlargement was observed on the lateral and anterior parts of the apophyses; the posterior part either remains unchanged, or becomes only slightly uneven.

Lateral radiographs show a small protuberance on the ventral part of the vertebral body, just below the superior apophysis. Evidently this is the radiological sign of the initial ossification of the anterior longitudinal ligament. In its further development the ventral and lateral corners of both apophyses start to protrude outside the body and form "lippings". In persons over 80 we have seen lippings in every case, though variations in the size, shape and distribution of lippings were very great. Several types of lippings are here illustrated (Fig. 12). They follow generally the direction of the intervertebral fibrocartilage: those lippings which are on the inferior apophysis border bend downwards, whilst those on the superior border bend upwards. In one of the men observed by us we found a complete fusion of all lippings and a concrescence of all small vertebral articulations supplemented by ossifications of the anterior longitudinal ligament. This was a definite case of Marie-Struempel-Bechterew disease with clinical symptoms such as pains and the impairment of function. A partial fusion of two or more lippings was found in four other cases. Of these four only one man complained of some pains during bending, three others felt quite well and did not complain of any pains even during maximum bending, extension and flexion. One case is especially significant: a man, aged 80, had spent all his life, except for the last ten years, in heavy physical work as a farmer, labourer in industry, etc. He had never consulted a physician and had never been seriously ill. The antero-posterior radiograph of his thoracic and lumbar region (Fig. 13) presents, besides the atrophy typical for his age, advanced hypertrophic changes. There is a partial fusion of lateral lippings between XII Th and I L and between I and II L. This resulted in restriction of the amplitude of movement in bending. There is only a slight increase
in the intervertebral space on the right side (bending was to the left) between III and II L. and between XI and X Th. It was very surprising to see a considerable difference in width of intervertebral spaces between the position of the spine in flexion and in extension (Fig. 14).

In people under 60 years of age lippings are mostly symmetrical; whereas in older people they generally become asymmetrical. Asymmetry was observed even in persons over 60 years of age in cases of scoliosis. In these people the development of lippings was more pronounced on the concave side of scoliosis (Fig. 15). Local asymmetry was also observed when the case history of an ageing person

![Figure 14](image1.png)

Fig. 14.
Lateral films of Fig. 13.
(A) Maximum extension. (B) Maximum flexion. (C) Routine film.

![Figure 15](image2.png)

Fig. 15.
Asymmetrical development of hypertrophic changes on the concave side of scoliosis.

![Figure 16](image3.png)

Fig. 16.
Between I and II L. left, the complete fusion of lippings. Trauma in case history.
(A) Routine. (B) In bending.
revealed a previous trauma. In this case an advanced hypertrophy was observed at the site of injury (Fig. 16).

In areas of hypertrophic bone, normal bone structure was observed in macroradiographs. This hypertrophic bone appeared to be merely a continuation of principal bone. This conclusion is in agreement with the results of workers on gross pathology of spondylosis deformans (Walkhoff, 1908; Pommer, 1914; Schmorl, 1953; and others). Differences of opinion exist, however, regarding genesis of hypertrophic bone. Some authors consider the latter to be of periostal origin, some of cartilaginous origin. This question is, in our opinion, of secondary importance because in both types of growth the most active role is played by osteoblasts and by the product of their activity, i.e., osteoid tissue. A much more important question, however, remains unanswered and that is the problem of post-adult bone growth. Is this growth the result of a local cause such as irritation or rubbing, or is the explanation to be found in the general status of the ageing organism, i.e. in the changed metabolism, the weakened hormonal activity, etc.? A partial answer to this question is given by the radiography of the spine in old dogs. Of 12 dogs studied eight showed considerable hypertrophic changes. The typical radiograph of the spine of a 12 year old dog is given in Fig. 17. The hypertrophic bone is seen not only in the frontal and lateral regions of apophysial borders but also along the attachment of the anterior longitudinal ligament. As in humans, these changes were accompanied by signs of bone atrophy.

The above observation allows some important conclusions to be drawn: (1) Bone hypertrophy is not a function of chronological age but depends rather on the general status of the ageing subject. (2) Local causes, such as "wear and tear", play a subordinate role in provoking the growth, because the function of the vertebral column in dogs differs very much from that in man. In particular a dog's spine does not sustain the weight of the body and does not participate in the maintenance of the erect posture. In dogs there is, therefore, no special reason for this "wear and tear". Nevertheless, the ageing signs in the vertebral bodies of a dog's spine are very similar to those observed in humans.

The present findings do not, of course, solve all the problems of post-adult bone growth; but they serve to show the direction in which further study should be carried on.

In order to find out how far the development of hypertrophy would influence the amplitude of movements of the vertebral column, we have radiographed ageing people in the five positions already mentioned. A detailed report of this work will be given elsewhere, it will suffice to give here only those findings which have a direct bearing on the subject of this study.

1. It was found that limitation of movement starts long before the appearance of hypertrophic signs in radiographs. Early limitation was especially apparent in our group of white-collar workers or in those who had not been recently accustomed to sustained physical effort. Some restriction in the amplitude of movement may even begin to show at the age of 35.

![Fig. 17.](image)

Hypertrophic changes in macroradiographs of spine of 12-year-old dog. Vertebrae are cut in halves with the zig-saw.

2. We were unable to correlate the extent of the development of hypertrophic signs and the degree of the limitation of movement. Some persons with a minimum development of hypertrophy had quite a limited amplitude of movement; conversely those with a conspicuous hypertrophy might have a surprisingly wide amplitude of movement.

3. The limitation of movement in the vertebral column is to some extent compensated by the movement of the body in hip and knee joints. Persons with completely or partially fused vertebrae, when lateroflexing their spine to the left, tend to lower their pelvis by flexing the left leg in hip and knee joints. Ageing men present initial and well-developed
hypertrophic signs in earlier decades than women. The reverse was seen in the development of atrophy.

**Historadiographs of vertebrae in the area of lipping**

Historadiographs of vertebral lipping show in general a picture of the bone very closely similar to that of the principal bone. At the margin of the lipping a thin layer of compact bone is observed which encloses a mass of spongy bone. The compact bone in the area of the lipping is not so well differentiated as that in the principal bone; it resembles rather the zone of preparatory calcification which is observed in growing bone. The laminar structure of this zone, however, is quite clearly visible. The lateral surface of compact bone in the area of lipping is mostly uneven and the thickness of this compact layer is consequently very variable (Fig. 18). The trabecular structure of lipping and principal bone are identical. There are no differences in their laminar structure, in the amount and distribution of intraosseal lacunae, nor in the distribution of the various bone canals. The only difference lies in the decrease in numbers of trabeculae in the lipping. This difference is very conspicuous because in the principal bone itself the number of trabeculae is diminished as a result of the atrophic process. Fig. 19 shows how the trabecula of the principal bone continues into the lipping.

The historadiographic signs which we consider pathological have already been described. We may only add that in the area of peripheral destruction the compact bone acquires a “crumbly” appearance. These “crumbles” (evidently those of calcium) seem to be located separately from the bone. Sometimes dentations are seen on the principal bone in the area of peripheral destruction.

Wherever calcification has originated in the bone, the same picture was observed as in lipping. Such calcification should really be called “ossification”; but if it develops at some distance from the bone it is seen as a structureless accumulation of calcium. This observation, which is possible only in studying a genuine, undecalcified bone, is very interesting as it contradicts in some way the biochemical study of calcifications and ossifications by Wells (1910). This author assumed that there is no difference in the morphological structure of either, since he could not find any difference in their chemical composition.

The main radiographic variations in different parts of the ageing vertebral column are as follows:

**Cervical vertebrae.** Moderately developed lippings which are seen mainly in the antero-inferior parts of vertebral bodies are shown by means of lateral radiography. In cervical vertebrae the development of the atrophy precedes that of the hypertrophy. Hypertrophic changes are seen on the periphery of the massae laterales and in the area of the intervertebral articulations. We shall not describe these
changes in detail here, as their description may be found in the extensive works of Schinz et al. (1952) and Koehler (1953), particularly in the chapters dealing with the radiographic symptomatology of spondylitis-spondylosis deformans. When deformities are not accompanied by permanent pains or discomfort or by considerable restriction of function, they have to be treated as signs of normal ageing.

Thoracic vertebrae. We do not consider the "senile kyphosis" of the thoracic vertebrae, as described by Junghanns (1931), Maurice (1933), Polgar (1937) and others, to be a prerequisite of normal ageing. In our material, only one case with complete ossification of ligaments and concrescence of ventral parts of thoracic vertebral bodies could be considered to be definitely pathological. In our opinion "senile kyphosis" is a relatively rare complication of normal ageing hypertrophy. We had the opportunity of studying radiographs of the skeleton, including thoracic vertebrae, of some old people over 100 years of age. These films were made in an expedition to the Caucasus in 1938. The results of the studies carried on during this expedition were communicated by Basilewitch (1940) to the conference on the problems of ageing held at Kiev. The dorsal spine or any other part of the vertebral column of all these people (one of them claimed to be 134 years old) presented neither ossification of the anterior longitudinal ligament nor fusion of anterior lippings. Atrophic and hypertrophic changes remained very moderately developed even at this age.

Conversely, many authors have seen "senile kyphosis" accompanied by ankylosis in young people (Mau, 1929; Scheuerman, 1936; Knutson, 1942; Bischofsberger, 1949; and others). Thoracic vertebral lippings develop usually in lateral parts of the vertebrae instead of in their anterior parts. The typical radiological sign of these thoracic lippings is the so-called "beak", which is seen in the antero-posterior films of the dorsal spine.

The atrophic changes were usually more pronounced in the thoracic than in the lumbar vertebrae.

Lumbar vertebrae. Hypertrophic signs are seen in earlier decades than atrophic ones. In men occupied in heavy manual labour an asymmetrical development of lippings in the lumbar vertebrae was observed fairly frequently. Many small traumas, which are typical for manual workers, could have contributed to the more intensive development of hypertrophic bone at the site of the vertebral injury.

Thus, our material supports, to some extent, the conclusions of some earlier authors that heavy physical labour contributes to the development of spondylosis deformans in the lumbar vertebrae.

In men occupied in heavy physical labour, lippings in the lumbar vertebrae become apparent in earlier decades than in white-collar workers and in women.

We cannot say, however, that the rate of the development of hypertrophic signs in the group of manual labour proceeds faster than in the white-collar group. Rather the contrary is the case. All our labourers pointed out that after retirement stiffness began to progress more rapidly, especially in the lumbar area. In our aged dogs the development of hypertrophic signs was also mainly observed in the lumbar spine. This indicates that the development of hypertrophy in the lumbar vertebrae is governed not only by a mechanical moment, but also by some other factor still unknown. It may depend upon such features as special characteristics of blood and lymph supply to this area.

All the observations previously discussed show that the whole problem of the relationship between physical labour and the development of deformities in the lumbar spine is somewhat controversial. Its solution must await a detailed study of the whole subject.

We have not seen any signs of spondylolisthesis in radiographs of ageing people in our group; it is evidently a disease of younger persons.

The "phantom nucleus pulposus" (the presence of gas in the intervertebral spaces of the lumbar vertebrae) as described by Knutsson (1944), Gershon-Cohen (1946) and others, was not observed by us. It is possible that the erect position during radiography used by us did not favour the exposure of so small an amount of gas which may be present in this space.

We cannot confirm the indications of some authors about the disappearance of physiological lordosis in the ageing lumbar spine; some degree of lordosis was observed in all the ageing people examined by us.

Os sacrum and coccyx. Though the sacral bone is the most capacious reservoir of calcium, we saw radiological signs of general decrease in X-ray absorption only in case of extreme bone atrophy. The first signs of atrophy in the sacrum were observed in the region of the massae laterales. Usually these parts of the sacrum give in ventro-dorsal films a summarised reflection with the auricular surface of os ileum. Consequently, this surface could not be easily observed in a normal case. In the case of atrophy of the sacrum, the
auricular surfaces of os ileum become much more
clearly visible than under normal circumstances.

In some of our ageing persons a spotty lysis was
observed in the corpus sacri, where several areas of
decreased absorption without definite borders
became visible.

Nevertheless, the sacral bone is the most difficult
part of the vertebral column in which to detect bone
atrophy in radiographs. The same applies to the
coccyx.

The sacrum is relatively immune from hyper-
trophic deformities. We have observed them most
in the interior parts of the massae laterales as small
lippings which sometimes form a bridge between
the sacrum and the os ileum. In one case of lumbar
scoliosis, hypertrophy in the area of the right
lumbo-sacral articulation was observed on the con-
cave side of the scoliosis.

No hypertrophic deformities were observed in the
coccyx.

**DISCUSSION OF RESULTS**

Though this paper deals only with morphological
characteristics, the discussion of some general
problems involving the ageing of man cannot be
avoided.

The existence of an “ageing norm”, i.e. of normal
changes typical of a given age, is admitted by us.
Though these changes manifest the general withering
of the human organism, they are not accom-
panied by any symptoms which might be treated as a
disease. With this in mind we selected from our
study men and women who considered themselves
quite healthy and did not complain of any symptoms
which might be regarded as pathological. After
clinical and radiographical examination of their
vertebral columns, several persons were found to
have definite patho-morphological symptoms. The
majority of selected people, however, were quite
normal.

Some atrophic and hypertrophic changes found
in the vertebral column of these normal persons are
reported in this paper. Prior to the work of Bennet
et al. (1942) all hypertrophic changes in bones were
looked upon as signs of pathology. Even now if some
hypertrophic changes are found in radiographs of
the ageing spine of a person, he is reckoned to be
among the large group of people suffering from
“degenerative osteo-arthritis”. Meanwhile, at least
half of these people are normally ageing persons.
The diagnosis “degenerative osteo-arthritis” often
provokes unnecessary methods of treatment for
these normally ageing people, not to mention the
bad psychological effect on these healthy people.

Greying hair in the aged or loss of deciduous
teeth in infants are changes typical of the stage of
life in which they take place. They are certainly not
signs of disease. Sacrolysisation, once considered
pathological, cannot now even be regarded as
abnormal, yet it is not so very long ago that surgical
removal of hypertrophied processus transversus
was frequently performed. Many bone deformities
to be seen in people of 60 and over are not signs of
disease, they are merely indications of advancing
years.

It is an established fact that everyone over 50
years of age shows some signs of degeneration in
his joint cartilages or intervertebral discs. But this
degeneration is no disease. MacCallum in his
Textbook of Pathology (1937) writes about such
degeneration as follows (loc. cit. p. 66): “The term
degeneration is usually employed to indicate the
effect of an injury sufficient not to cause the death
of the cell but to disturb its metabolism to such a
degree that the raw material or the products of its
activities accumulate in it” and further . . . “It
would seem desirable, if possible, to abandon the
term degeneration entirely and to use others which
refer more accurately to the disturbance in meta-
bolism or to the actual injury of the cell. But even
if we attempted this, it would probably be un-
successful, for the words are so deeply rooted and
express so concisely a complex and obscure idea.”

These are the words of an authoritative patho-
logist but they show how vague is the definition
“degenerative” in the term “degenerative osteo-
arthritis”.

All the published data mentioned above together
with our own findings, both macroradiographical
and historadiographical, show that a border-line has
to be drawn between normal and pathological ageing
in bones, particularly in those changes which affect
the vertebral column.

In Table II we try to perform this task. The
radiological signs are divided into two groups, those
which are concerned mainly with X-ray absorption
and those in which changes in X-ray bone mor-
phology are more conspicuous. This subdivision has,
of course, a conditional character, and is used only for
the better classification of radiological signs. Using
this table for the conclusion as to whether a person
over 50 years of age shows signs of normal or patho-
logical ageing, we must not overlook one very
important factor, i.e. the adaptation of human
organism to changing conditions of life. It would
be a great psychological mistake to put an ageing
person into the category of pathological ageing
merely because he shows morphological symptoms
of the pathological group. Subjective symptoms of ageing are of primary importance. Several persons in the group we investigated have adapted themselves to the pathological conditions in their spine and had no complaints. Theoretically they were sick, practically they were healthy. We are inclined to agree with our old men who say they are well rather than with their morphological data which show that they are not.

Historadiographical investigations of atrophic and hypertrophic processes in bones are still in their infancy. It can, however, already be said that they

have opened new vistas for bone studies. In addition to the opinion of M. Schmidt regarding the difficulties in our contemporary methods of histological bone study, we may quote also the following words of Beck (1925) who has written one of the best essays on bone atrophy: “The principal difficulty in bone study arises from the failure of contemporary morphological methods to differentiate between the bone which remains uncalcified and that which has been decalcified” (translation ours). All those acquainted with historadiography will say that no such difficulty exists for this method. As soon as our methods of cutting genuine bone have improved, and when a finer grain emulsion is available, the 

3. Ageing signs in the vertebral column can be detected and followed in their dynamic changes by the method of macroradiography.

4. A table is proposed to show the differentiation between normal and pathological ageing signs in the spine.

5. Advantages of the historadiographical method in the study of ageing vertebrae are emphasised.

6. Historadiographical evidence is presented to show that hypertrophic bone does not differ in its structure from principal bone.

7. Historadiographical evidence shows that the process of bone decalcification (particularly in the vertebral column) does not occur via the osteoclasts

Conclusions

1. The contemporary tendency in medical literature to treat every chronic, hypertrophic or atrophic process in ageing bone as pathological is questioned.

2. It is shown that bones in general and the spine in particular pass through regular and typical changes during ageing.

TABLE II

SCHEME OF DIFFERENTIAL DIAGNOSIS BETWEEN NORMAL AND PATHOLOGICAL AGEING IN RADIOGRAPHS OF Vertebral COLUMN

<table>
<thead>
<tr>
<th>X-ray absorption</th>
<th>Atrophy</th>
<th>Hypertrophy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Moderate decrease of absorption; general; os sacrum comparatively normal</td>
<td>Extensive decrease of absorption; vertebral bodies have a papyraceous outlook; often local atrophy of os sacrum</td>
</tr>
<tr>
<td>X-ray morphology</td>
<td>Vertebral bodies preserve normal bone structure; sometimes merely vertical trabeculae are seen; calcifications in soft tissues</td>
<td>Compression fractures of one or several vertebral bodies; cavities inside of spongiosa bone or destruction on the periphery of compact bone; calcifications inside of vertebral bodies; none or few calcifications outside vertebrae</td>
</tr>
</tbody>
</table>
alone. The possibility of halisteresis in the mechanism of bone atrophy is discussed.

8. Limitations in the amplitude of movement of the ageing spine as seen in radiographs are shown.

9. Some data on spine-ageing in dogs are given and the results are discussed in connection with the ageing of human bones. It is emphasised that the process of ageing of the spine in dogs proceeds along the same line as in man.

ACKNOWLEDGMENT

This work has been supported by a grant in aid from the Atkinson Charitable Foundation, Toronto.

SUMMARY

An attempt is made to systemise our existing knowledge on the radiology of the ageing vertebral column and to discuss all those radiological signs which appear to be quite typical for the normal (physiological) ageing process. Historadiography (microradiography) was introduced to this study for the examination of vertebrae in both the normal and pathological ageing process. Radiography of the spine in motion of living ageing persons was also carried out and its results are discussed. Microradiography and historradiography of vertebral columns in ageing dogs were included in this research in order to compare the process of ageing in human and animal spines. The results of the study showed that ageing of the vertebral column of both dog and man follows along approximately similar lines in spite of the fact that the canine vertebrae do not support the weight of the body. Seventy-five men and women were chosen for this study of whom 69 were over 60 years old. Results showed that the normal ageing signs may be observed in persons who do not complain of any pain or even discomfort. Both bone atrophy and bone hypertrophy develop together in the ageing vertebral column. Vertebral atrophy is shown to be distinct from "sénile ostéoporose" which is a disease with typical clinical symptoms. Historradiographs of vertebral atrophy in normal ageing give new facts in the mechanism of bone decalcification during atrophy. Atrophic bone is shown to lose its calcium not only via osteoclasts but also through other channels. Consequently the old theory of halisterthesis has again to be revived. Historradiographs also show that the bone structure in the case of normal ageing in the area of vertebral lippings is quite identical with bone structure in the principal bone. Hypertrophic process is thus a continuing bone growth rather than development of an abnormal bone. Such abnormalities as the presence of cavities and the impregnation of these cavities with calcium, bone destruction, etc., were only found in cases of pathological hypertrophy. These facts show that it is necessary to revise the conception that every lipping is a sign of hypertrophic arthritis since these hypertrophic manifestations in old age may be found in quite normal persons who show no clinical symptoms of arthritis. The peculiarities of the normal ageing process in different parts of the vertebral column are discussed.

REFERENCES

Bennet, G., Waine, H., Bauer, W., Changes in the Knee Joints in various Ages, 1942 (Commonwealth Fund, New York).
Clark, G., Radiology, 1947, xlix, 483.
Cobb, M., Skeleton, in Coudry's Problems of Ageing 1952 (Williams and Wilkins, Baltimore).
Gersthom Cohen, J., Amer. J. Roentgenol., 1946, lvi, 43.
Goebcke, C., Unfallheilk., 1931, viii, 136.
Knutsen, F., Acta Radiol., 1942, xxiii, 173; 1944, xxv, 593.
Lamarque, P., Radiology, 1936, xxvii, 563.
MacCallum, W., Textbook of Pathology, 1937 (W. Saunders, Philadelphia).
Marchand, F., quoted by Beck.
Maurice, G., Physiologie-pathologie et indications therapeutiques, 1933, xii (Masson, Paris).
Polgar, F., Fortschr. Röntgenstr., 1937, lvi, 208.
Ribbert, H., Virchows Arch., 1880, lxx, 448.
Roessle, R., Aschoff's pathol. Anatomie, 1913, i, 298.
Scheuerman, H., Fortschr. Röntgenstr., 1936, lii, 1.
The following works on bone historradiography have appeared in 1954: