to be. But the truth of things is after all their living fulness, and some day, from a more commanding point of view than was possible to any one in Agassiz's generation, our descendants, enriched with the spoils of all our analytic investigations, will get round again to that higher and simpler way of looking at Nature. Meanwhile, as we look back upon Agassiz, there floats up a breath as of life's morning, that makes the world seem young and fresh once more. May we all, and especially may those younger members of our association who never knew him, give a grateful thought to his memory as we wander through that Museum which he founded, and through this University, whose ideals he did so much to elevate and define.

WILLIAM JAMES.

HARVARD UNIVERSITY.

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*ON THE EFFECTS OF DISEASE AND SENILITY AS ILLUSTRATED IN THE BONES AND TEETH OF MAMMALS.**

I WAS very glad to respond to the invitation of your commitee to address you, for the reason that I have been for a long time interested in studying the effects of diseased action and senility, I hold that they are closely related and capable of being compared in precise ways with other morphological processes.

Am I right in assuming that to no other organization is it so appropriate to present the results of my investigation as to your own?

In a scientific sense the use of the words 'morbid' and 'pathological' cannot be sustained, for it assumes the existence of morbific principles. One might speak as reasonably of the use of the words 'dirt' or 'weeds' being warranted in treating of exact conceptions.

Disease tends to interfere with efficiency —in whole or in part—of the organism in which it is manifested. But this statement, you will observe, in no way relates to etiology. The difference between disease and senilty is apparent rather than real; for senility, like disease, is a condition tending to inefficiency. Many senile states resemble diseased states and include calcification, absorption, fatty degeneration, etc. But if these processes help the organism by preparing it for its work they cannot be called perversions, since all of them are present in early and confessedly normal states of the economy. Calcification is a normal process, whether we see it in the perpendicular plate of the ethmoid bone in the young adult or in the walls of blood vessels in the aged; absorption is a normal process, whether it is seen in the roots of the deciduous teeth in the young or in the orbito-temporal septum of the aged; fatty degeneration is a normal process, whether it takes place in the mature placenta and prepares the way to parturition or occurs in the form of an *arcus senilis*. But the results of these processes are enormously divergent, one maintaining physiological activities, the other hastening to decay and death.

Senility is of no definite period and, therefore, is without accurate limitation. The postulate that 'wear and tear' on tissues or organs which cannot be replaced occur in direct ratio to use is accepted. In low forms of life large portions of the economy, and some tissues even in the highest forms, are discarded and new ones take their place. Epithelial elements are constantly being thrown off, and in many animals teeth are lost when no longer of service and others are developed to supplant them. But in old age of high grade organisms we witness loss, rather than gain, both in organs, like the teeth and hair, and in tissues, as muscle fibres in the capillary blood vessels. So far as man is concerned, this period is, on the whole, included in the time when he is no

*A lecture delivered before the Graduate Club of the Biological Department of the University of Pennsylvania, December 7, 1896.

longer virile. I venture to call it the post-genetic period. The term senility, in addition to the usual ontogenetic sense, will be employed to express the changes that go on in a given group of animals on the decline from its acme of evolution, and attempts will be made to correlate these states with those occurring in the individual. (A. Hyatt.)

I propose to submit a number of facts which, for convenience, I have placed under the head of propositions, the number and variety of which give a clue to the intricacy of the subject.

It will be taken for granted throughout that the subject of variations of structure as usually limited has been carefully considered and set aside, for these do not invalidate any of the propositions.

I. *Reversion to lower types is sometimes witnessed in the senile human skull.*

Outside of Primates no mammal exhibits an orbitotemporal septum. In the senile human skull thinning, and often notable absorption of the septum is almost constantly exhibited.*

II. *Complex bones are sometimes analyzed in part by the manner in which absorptive processes occur in them.*

Many examples can be cited to illustrate the fact that bones originally separate tend to localize effects of diseased action even when the lines of separation between primal parts disappear. It is not expected that when the precoracoid bone of the cod is hyperostosed—a condition which has been often detected—that other portions of the suspensorium should participate. Neither do we find that when one-half of the lower jaw of a kangaroo is diseased that the other separate half should be involved. In the domestic cat the halves of the lower jaw are disposed to unite in old age, but even in this animal effects of inflammatory processes may be confined to one-half of the bone. In a specimen of an old cat in the Cornell collection the symphysis was united, the entire mentum thickened; but the right side of the jaw was without incisor teeth and was much larger and thicker than the left, which was provided with teeth.

The center for the premaxilla in the so-called superior maxilla of the human subject is sometimes absorbed after the suture lines between the bone and the maxilla proper have been obliterated.* In the malar bone of the human subject the lower half is sometimes separated from the upper by a suture. The bone when thus marked is said to be bipartite. The skull of a syphilitic subject in my possession exhibits absorption of the lower half of the left malar bone. Since the bipartite bone is exceedingly rare, it is probable that the specimen had not possessed the suture and that the absorptive process had stopped when the area corresponding to a distinct center of ossification had been covered. Even if the bone had been bipartite the circumscription of an absorptive process to an individual bone would have been none the less striking. In old age the peripheral venous openings on the bones tend to become enlarged. The arrangement of these openings sometimes defines the regions occupied by epiphyses which have long since disappeared. In the femur of the senile dog, for example, the line of separation of the distal epiphysis from the shaft is indicated by the venous foramina being enlarged on the periphery. I have never observed such disposition to manifest itself in vigorous adults.

III. *Bone processes are sometimes increased in size in senility, or appear in places where they are not seen in antecedent stages, though occurring normally in the species of related groups.*

In the aged human subject the styloid process is sometimes longer than in younger

* I described this in *Am. Journ. Med. Sci.*, 1870, 405.

* Ibid, p. 403.

adults. This is caused by ossification of the stylo-hyoid ligament, which is often represented by a separate bone in lower animals.

The domestic cat exhibits, as a rule, no tubercle on the lachrymal bone. In the senile skull of this species the tubercle is present. It is of interest to note that among the following skulls of *Felis* in the Academy of Natural Sciences, Philadelphia, and the National Museum, Washington, four only (*F. eyra* and *F. yaguarundi*, *F. catus* and *F. caracal*) exhibited the lachrymal bone as it is in the vigorous adult of *F. domesticus*. In the following species the tubercle was present, though small: *F. pardus*,* *F. rufus*, *F. canadensis*, *F. pardalis*,† *F. leo*. In the following it was large and formed precisely as in the old examples of the domestic cat, *F. caligata*, *F. onca*, *F. concolor*, *F. tigris*. Thus the form of the lachrymal bone in the old cat reverts to that of the prevalent type, not by absorption, as in Proposition I., but by the creation of a conspicuous process of bone.

The senile cat again exhibits hyperostosis of the lateral process of the frontal bone (post-orbital process) as well as of the ascending process of the malar bone. Thus these processes approach each other and indicate the tendency to union shown in related efficient forms of the clawed mammals in which such union actually takes place.

IV. *Both the upper and the lower jaws of certain mammals tend to elongate in old age.*

The animals already named possessing long jaws have the intervals between some of the premolars widened in senility. The vigorous greyhound has the third lower premolar almost in contact with the fourth, while in the jaw of an old mongrel it is widely separated therefrom. In a general way, it may be said that the last three premolars are all more widely separated from one another than in younger individuals. The cause appears to lie in the disposition for the jaw to extend forward somewhere in front of the region of the molar teeth; for the extraordinary wear that sometimes takes place between the lower canine and the upper outer incisor can be explained in no other way. In an old dog (No. 22,563, U. S. Nat. Mus.) the lower canine had pressed against the upper second and third incisors and had worn away the teeth. The permanent premolars always lie close together when recently erupted. This disposition appears to be a corollary to the law of the vertical succession of these teeth.

The large permanent teeth following the small deciduous teeth in exact infra-position compel the former to lie close together. But they tend to separate afterward, especially for the first and second to separate from the third and fourth. In the domestic cat the interval between the second and third teeth is more variable than between the others. As a rule, it is but 2 mm. in front of the third tooth, though it may be as much as 5 mm. These proportions are maintained throughout life in this species, so far as I know.

In the dog we have a much greater variety, since in the different breeds the face axis is modified. In the short-faced types the premolars retain their early crowded condition, or this may even be exaggerated; while in the long-faced types they tend to be separated, excepting the third and fourth teeth, which remain, at least in an example of the greyhound above noted, close together.

Putting aside the pug dogs and bull dogs, the variations in the intervals between the premolars are marked and appear to be independent of the relative length of the face to the brain case. In the St. Bernard the first lower premolar (counting it as a re-

* A small tubercle may occur in this species as a variation.

† Absence of tubercles may be noted as variations.

tained deciduous tooth) is nearer the canine than in any other variety. The interval between the third and fourth upper premolars is conspicuous in the rather short-faced Esquimaux dog and the St. Bernard.

Since in the domestic dog the increase in the length of the lower jaw occurs in phyllogeny (artificially in breeding) and in ontogeny the form is of exceptional value in the philosophic study of senility and diseased action. But the subject is correspondingly complex. So far as I know, no collections are available for its satisfactory study.

In old examples of *Glossophaga soricina* and *Pteropus poliocephalus* the intervals between the premolars is much greater than in younger individuals.

V. *Senile forms of one species may resemble in essential characters the typical forms of an allied species.*

The appearances forming the basis of this proposition may be found not only in aged animals, but in the vigorous stages of an allied species as well. Thus, an old example of *G. soricina* resembles the typical form of a closely allied species, *G. truei.**

VI. *Gross variations in the forms of teeth in closely related and highly specialized animals indicate that the types have become exhausted of their capacity to precise adaptation and are degenerating. The forms that degenerated teeth assume are those that simulate senile changes in animals less highly specialized than themselves.*

One of the most familiar changes incident to long use is the wear of the teeth. It would appear that the height of the tooth is in some degree proportional to the work that is expected of it; that the crown represents the accumulation of a definite amount of material to be used up in grinding. We have often occasion to note the effects, upon the jaws themselves, of the lowering of the height of the crowns of the teeth.

The fox bats, which are frugivorous, are composed of fifteen genera. With a single exception (*Pteralopex*), they retain molars whose cusps have almost disappeared. The fact can be otherwise expressed as follows: The departure from the habit of the consumption of animal food to that of fruit leads to rather abrupt changes in the tooth form, by which the cusps are rapidly worn away, one insular genus alone maintaining its ancestral cuspidation.

In the New World fruit-eating bats we have examples of similar abrupt changes, though carried out in a less uniform manner. The forms do not constitute in themselves a family, but are grouped irregularly within the family, most of the members of which retain carnivorous habits, and at best the lines between the carnivorous and the frugivorous types are not sharply defined. In the Vampyri out of thirteen genera the molars of one genus only (*Hemiderma*) have lost their cusps, while in the Glossophagina out of six genera the teeth of one doubtful member of the group (*Phyllonycteris*) have lost their cusps. But in the Stenodermina, of thirteen genera, all the cusps have been lost, or are retained in the shape of the merest rudiments of the carnivorous plan. In two remote genera (*Cephalotes* and *Ectophylla*), one in the Old World and the other in the New, the concave depressed molar crown has been so worn away as to bring the grinding surface of the enamel cap near the alveolus and apparently to create a new *system of cusps*, as if the tooth were a slate on which had been placed a problem which demanded that an older problem previously recorded on the same surface should be removed before the terms of the newer one could be stated. In the senile form of every bunodont mammal the molar teeth tend to have the crowns diminish by wear and all traces of cuspidation to be lost. To my mind there is no difference between the loss of all cusps in the last premolar and the molars of an old dog, and the way

* Proc. U. S. National Museum, 1896, 779.

in which cusps are lost in bats in passing from an insect-eating to a fruit-eating habit. The fruit-eating bats might be called senile forms, because they lost their cusps, just as reasonably as we may use similar language in describing an old dog. Both forms exhibit degeneration effects; in one it is phyllogenetic; in the other it is ontogenetic.

VII. *Entire loss of teeth in the human subject from old age will often be followed by hyperostosis which presents three kinds nearly answering in position to the three series of teeth, the incisors, the premolars and the molars.*

The same law which created the differentiation of the teeth continues to operate after the loss of teeth. This is modified by the characters of chronic rheumatism and syphillis. The best examples in illustration of the proposition are met with in the jaws of savages.*

VIII. *The manner of obliteration of sutures in the skull of mammals may be definitive.*

The parieto-squamosal and the sphenoido-squamosal sutures rarely disappear in the human skull, no matter how old the individual. The suture last named disappears in the dog in the early stages of senility. The two forms are thus distinguished as readily as by the employment of other characters. We do not hesitate to distinguish by rates of disappearance of cranial suture lines the Ophidia from other reptilian orders.

IX. *Muscles modify the shapes of long bones in proportion to the length of time they have been exercised.*

The power of the flexor muscles of the limbs, on the whole, is greater than that of the extensors. It is the flexors that hold the extensor tendons firmly against the long bones, even, indeed, if they do not create grooves for the accommodation of their tendons. The longer the time the extensors are thus held against the bones the deeper become the grooves. Hence the relatively deep grooves on the extensor surfaces of long bones, as in the patellar notch and the grooves on the distal end of the radius, tibia and fibula in old animals. In an old cat in the collection of Professor Wilder at Cornell University the groove for the *Tibialis posticus* was converted into a bony canal.

Proposition IX. is also illustrated in the groove for the *Extensor longus pollicis* of the common brown bat (*Adelonycteris fusca*) becoming deeper in old individuals. At times the sides of the groove become enormously thickened by hyperostosis.

X. *In ontogeny a senile form of an annually recurrent structure may resemble the juvenile form and recall in phyllogeny the primitive form.*

The horn in an old specimen of *Cervus canadensis* tends to reassume the form of the spiked horn of young specimens, which at the same time recall the shape of the primitive horn in Pecora generally.

XI. *Inflammation of bone modifies the shape in places which exhibit the greatest physiological activities, and these prepare the way to senile changes in the same regions.**

The deepening of extensor muscle grooves when carried far will, we assume, develop friction and with the friction excess of heat and with the heat inflammation and resulted hyperostosis. But excess of heat may arise from undue exaltation of functions of any kind. In the following instances it has been productive of grave results from the conjunction of restrained growth force in the halves of the lower jaw and the eruption of the incisor teeth.

In the lower jaw of the domestic cat whose permanent premolars are just being erupted the symphysal articular surfaces are nearly smooth; in that of an animal

* Proc. Acad. Nat. Sci., 1893, 11.

* In studying the jaws of the domestic cat I have been struck by the frequency of effects of traumatism, especially of fractures of the teeth. It will be assumed that in the above statement all instances of disease following injuries have been excluded.

whose premolars are erupted the surfaces are uneven by the processes interlocking to fix the symphysis securely. At the same time that this change is announced the incisors are coming in place. The second tooth lies at first back of the first and third, so the alveolar region is twice as broad as when a little later all three teeth are in line. Thus great activities of the symphysal and alveolar regions are coincident. It is at this stage that the cat is prone to disease at the mentum. In forty-eight examples of adult lower jaws examined from your cabinet, thirty-three showed hyperostosis of the alveolar region for the incisors, the antero-posterior diameter being 5 mm. (a measurement twice that which is normal), with loss of at least one incisor, at a time when the sectorials were but slightly worn, while the jaw in other respects showed fully adult characters. In studying senility we are prepared to find the mentum exhibiting frequent changes from the normal. The entire region is often hyperostosed or carious; the incisors in part or entirely lost, and even the canines loosened or lifted by filling up of the bottoms of their sockets. In this manner a slightly plus physiological activity in the young has prepared the way to variation in adult life and to characteristic changes in old age. In the collection I found seven examples of these changes in very old bones. I am informed by Dr. Burk that, since the greater number of cats used for dissection are not over two years old, the number of senile examples in the collection is probably much less than would be found to be the case if data could be collated from life histories of the species secured under average circumstances.

It is impossible to say which of the characters outlined in the above propositions (save alone Prop. VI.) can be transmitted. It is safe to assert that many of them are sporadic in character, though I do not believe them to be adventitious.

As the individual nears the time of its own extinction it experiences changes in the composition of its tissues and gross variation in characters. Groups of animals which are also approaching extinction behave in a similar manner. Ontogenetic comparison in the first case should be made with the phyllogenetic comparison in the second as well as with the more efficient of their own types. The aged individuals of the domesticated Bovidæ, for example, should be compared with all the younger adult individuals of the Aurochs.*

The senile horse should, in like manner, be studied with the phyllogeny of the group to which it belongs. Since our knowledge of this is relatively precise, I have long thought the comparison would be of exceptional interest.

The difficulty in procuring material for studies in senility is very great and probably accounts for the slight attention which has been given the subject. I wish in this connection to gratefully acknowledge receipt of specimens from Professor Burt G. Wilder, Cornell University, from Dr. Charles Burk, University of Pennsylvania, and from Messrs. F. W. True and F. A. Lucas, of the U. S. National Museum. I respectfully solicit additional material from those who do not object to having their cats, dogs and other animals used for scientific study after they have ended honorable careers as household pets.

Harrison Allen.

Philadelphia, Pa.

* G. S. Miller, Jr. (Science, November 20, 1896, 744), in abridging Büchner's account of the degenerate and lingering European bison herd, speaks of the prevalence of abnormal conditions in parts of the skeleton. According to the tenets of the above essay, these conditions will yield, when studied, the best results when compared with those found in other vigorous groups of genera of the Bovidæ, as also with effects of age and disease in the life history of an individual of any one of the species.