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(numerical or not) similarly connected. I say in general, because perhaps the preferable view of the problem, which is the object of our method, is to consider it as that of reducing certain algebraic functions, whether they be supposed equal to zero or not, to the form of a sum of algebraic powers.

Should it be thought that in the present article I have dwelt at unnecessary length on certain points, I should urge by way of apology, that before it can be fairly estimated all knowledge must be systematized. And I would add, that all knowledge is probably capable of being so dealt with, to an extent of which we can as yet form no idea.

2 Church-yard Court, Temple,
November 8, 1847.

XVIII. Observations on the Geological Age of Bone-Caverns.

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THE geological period during which the caves of England formed the residences of wild beasts and cemeteries for the bones of their victims as well as themselves, is a subject of great interest, and can be best, if not exclusively ascertained, by comparing their animal remains with those of sedimentary deposits.

If a cabinet collection of cave specimens be contrasted with one of the Pleistocene freshwater formations, so great will appear the excess in the former, of small animals allied to, or identical with, those of our own times, that a date even more modern than "Pleistocene" might reasonably be given them. With a view of making a more just comparison, the following table has been constructed, showing the living and extinct animals common to both, and peculiar to each.

Peculiar to sedimentary deposits.		Peculiar to caverns.		Common to both.	
Extinct.	Living.	Extinct.	Living.	Extinct.	Living.
Macacus plicocenus.	Castor Europæus.	Ursus priscus.	Vespertilio Noctula	Ursus spelæus.	Felis catus.
Palæospalax		Machairodus	Rhinolophus	Hyæna spelæa.	Arvicola
magnus.		latidens.	ferrum-equinum.	Felis spelæa.	amphibia.
Trogontherium		Lagomys	Meles Taxus.	Elephas	Cervus
Cuvieri.		spelæus	Putorius vulgaris.	primigenius.	Elaphus.
Rhinoceros		Equus plicidens	Putorius erminius.	Rhinoceros	Cervus
leptorhinus.		Strongylaceros	Canis Lupus.	tichorhinus.	Farandus.
		spelæus.	Canis Vulpes.	Equus fossilis.	Capra
			Arvicola agrestis.	Asinus fossilis.	Hircus.
			Arvicola pratensis.	Hippopotamus	Bison priscus
			Mus musculus.	major.	
			Lepus timidus.	Sus scrofa.	Aves (?)
			Lepus Cuniculus.	Megaceros	
				Hibernicus.	
				Cervus Bucklandi.	
				Cervus Capreolus.	
				Bos primigenius.	
				Bos longifrons.	

* Communicated by the Author.

Thus of forty-two distinct Mammalia, twenty are found in both positions, seventeen are limited to the caverns, and five are found exclusively in freshwater strata.

From a mere survey of such a table, conclusions as to the relative age of the two series would be inaccurate; and it becomes necessary to consider the various circumstances under which each may have arisen, and the influence which the habitats of the various animals may have exercised upon the position of their remains.

The valley of the Thames, in many places so abundant in animal remains that a metropolitan churchyard could hardly boast of a greater collection of bones, presents some peculiarities worthy of attention, and bearing closely upon the point. The bones are in general in a good state of preservation, and often make up nearly the entire skeleton; but occasionally some fragments are met with, not resulting from original violence when deposited (as they are often surrounded by the most delicate freshwater shells) or careless removal, but apparently broken before carried to their place of interment. The frequency of animal remains appears to be just in proportion to their size, the small bones of large mammalia being much more uncommon than the larger ones, and the young of such animals as the Mammoth, Rhinoceros, and Hippopotamus being rarely met with, whilst all indications of the smaller genera so common in caverns are altogether absent. I have collected from these Pleistocene beds, chiefly at Ilford, remains of the following animals:—Mammoth, Rhinoceros, Ox, Auroch, Horse, Irish Elk, Deer, Bear, Sheep, Pig and Bird; but the first four only can be called abundant, and of these the Mammoth and Rhinoceros are at least ten times more frequent than the other two—the rest are but seldom met with. The Bear is the only representative of Carnivora, and of it only one specimen has been found; and the only evidence of a Bird consists of an ulna, of which more will be said hereafter.

Upon looking at such a collection, it is impossible to suppose that it can represent the whole creation of any geological period, or that such a mass of Mammalia can have been without an ample number of destroyers; for although the Tiger and Hyæna have been found in deposits of the same age, they are rare, and bear a very insignificant proportion to the Herbivora.

The bone-caverns reveal a set of circumstances exactly the opposite of the above. In these, several genera of Carnivora are abundantly preserved; and the bones with which they are associated belong either to a class of smaller animals or the young of the larger ones, and a collection of these remains equally fail in presenting us with representatives of an entire

race. But if the two be united, an intelligible system is established—the young Mammoth and Rhinoceros meeting with their parents—Herbivora and Carnivora mixing for the first time perhaps in undreaded society, form a natural series of animals of all habits and sizes.

All this may appear but a coincidence, unless it can be shown why there should have been this separation in the position of their remains; but the habits of the various animals will yield the explanation.

Upon the approach of natural death or any catastrophe, the wary and active Carnivora would generally retire to, and die in, their dens; whilst the larger Herbivora would be more likely to leave their bones upon the plains, to be subsequently swept away and entombed by natural operations. But it was not by any sudden or violent action that the great accumulation of remains in either position took place. For ages Tigers and Hyænas did their office, and thousands became their victims. Animals of all sizes were exposed to their attacks; but the smaller ones, and the younger and weaker individuals of the larger class, were their most common prey; and it would rarely happen that such died a natural death, or if they did, their bones would seldom fail to become the property of Hyænas, hence they are almost exclusively found in caverns; but the larger and more formidable Mammoth and Rhinoceros must have less frequently met with violent death; or when this did occur, their bulk and weight would be against their finding their way into the dens of Hyænas, and their skeletons, more or less mutilated, would be left to be swept away and interred in fluvial deposits, where they are now so abundantly found. The broken bones to which I have alluded may have had such an origin; they exhibit no teeth marks, but otherwise, in appearance, would bear out such an idea. Of six bones of Birds found by Dr. Buckland at Kirkdale, the ulna occurred four times, which led him to the ingenious observation that the strong quill-feathers attached to that bone may have prevented it being devoured. It is singular that the same bone should be the only one preserved at Ilford; especially as a row of strong tubercles proves it to have belonged to some powerful bird of flight, consequently with a strong set of wing-feathers; and if a similar explanation of its preservation be admitted, it affords additional strength to such an inference.

The accumulation in caverns may in reality have occupied more than one geological period; and long after the last hyæna ceased to exist, have been added to by the Wolf and Fox, to whose operations may be attributed the introduction

of such animals as the Hare and Rabbit; whilst the Bat, Mouse, and Vole may have been at some other time not unwilling tenants of the same caves. But even assigning to all the same antiquity, for reasons given above, it is not surprising that these should be found only in caverns. The *Equus plicidens* and *Strongyloceros*, perhaps the only animals whose sole existence in caverns is difficult to account for, may yet find their representatives in sedimentary deposits: the latter is so uncommon that but one specimen has been met with, and that in Kent's Hole, and at Ilford remains of gigantic deer, too fragmentary to declare their affinities, are frequently found.

The remains peculiar to freshwater strata are such as might be expected to appear there. The Monkey would be an unlikely prey to Tigers and Hyænas; and the Water-Mole, Castor and gigantic Trogontherium, from their amphibious and wary habits, would rarely become the prey of land Carnivora; and if preserved at all, would mix with deposits continually going on from the element in which the greater part of their lives was passed. The occurrence of *Rhinoceros leptorhinus* exclusively in these formations does not appear so remarkable, when it is recollected that the genus itself is comparatively rare in caverns; and some peculiarity may have existed in this species, rendering it less liable than the other to become the prey of carnivorous contemporaries; and it is well-known that several living species, differing less from each other than the extinct ones did, have very different habits.

It must not be forgotten, that future discoveries may considerably alter inferences derived from our present knowledge on this subject. It is impossible to predict what may hereafter be revealed by chance or the labours of the geologist; and each year brings with it an increase to the number of fossil mammalia. But as the matter remains at present, there is nothing against the possibility, whilst many things tend to make it highly probable, that animals from the newer tertiary deposits were the contemporaries of those found in caverns; and that whilst the Mammoth and Rhinoceros, from their powers of defence, enjoyed a comparative immunity from attack, and left their bones in the slowly-forming aqueous strata, their younger and weaker associates frequently became victims to the appetites of fierce Carnivora, and were finally carried to the dens of Hyænas.

4 Bolton Street, Piccadilly,
December 1847.