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**THE EXTINCTION OF SPECIES.**

BY CHARLES MORRIS.

The story of the disappearance of species of animals and plants during the geological period, and their replacement by new species, is much too obscure to attempt to solve except to a very partial extent. Since life began upon the earth the process of extinction has been seemingly incessant, and still continues so, Man being perhaps the most efficient of all the many agents that have taken part in this process. As a rule, the extinction of forms would appear to have been gradual, and the simultaneous sweeping out of great numbers of species, which is claimed occasionally to have taken place, is open to question, from our lack of knowledge of the length of time really involved. There are, however, two instances in which such an extinction of numerous species within a comparatively brief interval appears certainly to have taken place, and it is these which I propose particularly to consider. These are the apparently sudden disappearance of great numbers of giant reptilian forms at the close of the Cretaceous epoch, and their replacement in the early Tertiary by numerous large mammals; and the similar sudden disappearance of a considerable number of large mammals in the Post-pliocene or the early Recent period, including the mammoth, the American horse, the giant sloths, etc. Although no other than general causes can be adduced for extinction as a whole, it may be that some particular causes can be suggested in connection with these two special instances.

As an important preliminary to this investigation, some consideration of the general causes of the disappearance of species is desirable. In the first place it is improbable that many, if any, species have ceased to exist in consequence of the direct assaults of other animals, except in the case of Man's destructive agency. A species, whose individuals are numbered by millions and whose range is ordinarily very extended, is not easily to be disposed of. Animal hostility, even when unrelenting and effective, is never governed by a fixed purpose of destruction. Its aims are minor and individual; food,

not destruction, being its purpose. The only animals which act largely together in the work of destruction are the ants, yet with all their intelligent combination for this purpose it is almost certain that no species of insect owes its extinction to ant aggression. Among existing animals there are certain carnivorous fishes whose destruction of other, helpless species is annually enormous, yet these depleted species far from disappearing, return each year in vast multitudes to their feeding grounds. So far as existing evidence goes, then, it seems probable that hostile aggression, while it may have occasionally been an indirect, has rarely been the direct cause of the extinction of species.

It is equally doubtful if extinction has been due, as a general rule, to lack of suitable food. This may have been the case with certain invertebrates adapted to very narrow food conditions, and with some highly specialized vertebrates, confined to a transitory condition of the food-supply. But ordinarily the food-supply, at least of vertebrates, is wide-spread and persistent, while most of the higher animals have some power of variation in this respect, and can adapt themselves to new kinds of food. It would seem most probable, on the whole, that extinction of species has been generally due to indirect rather than to direct influences. Species of animals and plants have rarely, if ever, disappeared through their destruction by other species as food, and rarely through a natural insufficiency of food. Most probably the usual causes of destruction have been adverse conditions of nature, and the competition of other species in the struggle for food.

Nature undoubtedly has been active in this work, her adverse influences being violent and wide-spread; storms, sudden and severe changes in temperature, long-continued floods, extensive droughts, and occasionally highly destructive volcanic or other convulsions. To such influences entire species may in some instances have succumbed, particularly where the adverse conditions were of long continuance, while other species may have been so greatly reduced in numbers and energy as to become incapable of sustaining themselves against the competition of more vigorous rivals. Among recent instances of this kind may be classed the destruction of large numbers of cattle and other domestic animals on the western plains in winters of great severity and deep snow-fall. This destruction takes place despite all the efforts of Man to prevent it, and would be

much greater but for human aid. On the other hand it must be said that these animals have been removed from their native habitat; and that their special exposure to danger is a result of Man's interference with nature's adaptations.

Organic competition takes various forms. An indirect struggle between species is constantly going on. The food supply is in every case limited, and is the object of an increasing contest between the individuals of a species and separate species, in which the most vigorous individuals or the best adapted species are likely to win. In this contest size and strength of a species are rarely assurance of success. Size may be detrimental, as necessitating more food, while strength is of little avail where the contestants are not directly pitted against each other. The mastodon, for example, needing great quantities of herbage for its food supply, might, in cases of severe drought, succumb to the food competition of the rabbit, or some still more insignificant creature, which, spreading in vast numbers over the country, devoured the sparse herbage and left its huge competitor to starve. An army of locusts has more than once brought great numbers of men to the verge of starvation, despite Man's intelligent and combined resistance. The potato bug is capable of depriving a nation of its food, and a blighting fungus may destroy the crop upon which a whole people relies. It needs all Man's care and prevision to prevent insect foes from destroying his food supply. The lower mammalia have no modes of defence against such assaults and no power of providing granaries of food against times of need. Thus hosts of herbivora may have frequently perished in consequence of an insect assault upon their food; and numerous carnivora, thus deprived of their food, may have similarly perished. Yet on the other hand, the lower plant-eating mammalia are much less exposed than Man to this special danger, from the fact that few of them feed, like him, on fruits and seeds, their general food supply being the abundant grasses, and the leaves and twigs of trees, a supply which is much less likely to fail.

An adverse influence, of the nature of direct assault, and one which at times may have been enormously destructive, remains to be mentioned. This is the aggressive action of the minute organisms known as bacteria, of which the disease-producing species have at times proved the most dangerous of all the known enemies of Man. At present, however, the indications are that they are much less

destructive to the lower animals than to Man, the difference being due to difference of life habits. Though bacteria and other disease-producing agents may at times in the past have attacked species of animals destructively, it is probable that they have played but a minor part in the extinction of species.

There is still another interesting natural condition to consider in our review of the general causes of the extinction of species. One tendency, which has particularly manifested itself in herbivorous animals, has frequently led directly to their destruction. This is the tendency to increase in size through the double influence of abundance of food and little waste of tissue through exertion. In the sluggish grass-eaters, dwelling on plains covered with rich herbage, or leaf and twig eaters in tropical forests, the nutritive agencies are in excess of those of waste, and these animals seem always to have tended to an increase in size, until those of least exertion and greatest powers of obtaining food became enormous in dimensions. An example of the same kind among the carnivora is the Greenland whale, which, while feeding on minute forms, obtains them in enormous quantities with little muscular exertion, and has in consequence become of extraordinary dimensions.

In the case of the herbivora this increase in size has exposed them to increasing danger of starvation in cases of great drought, and from the food competition of smaller but more numerous animals, and many species may have become extinct through this cause. It is probable that a struggle has long gone on between the two organic tendencies—on the one hand to increase in bulk; on the other to increase in activity—the victory finally falling to the smaller, more active, and more mentally energetic forms, through their ability to survive on less food and their superior powers of resistance to nature's adverse influences. It is perhaps mainly due to this that the bulky, sluggish and mentally dull creatures of the past have given way to the smaller but more active and intelligent animals of the present.

This leads us directly to the problem of the disappearance of the great Cretaceous reptiles—the first of the two special cases to be considered. The influences described may have had something to do with this event, but are far from sufficient to explain the sudden disappearance of so many species of animals of varied habitat, food and conditions of life. However far land animals may have been thus affected, the great ocean reptiles could hardly have succumbed

to these influences. Nature has been frequently credited with this destructive work, some world-wide convulsion being called in to do duty as an efficient agent. But this cataclysmic theory has been largely over-employed, and could hardly have confined its ravages to the larger reptiles, of sea and land alike, while leaving the smaller reptiles and the contemporary mammals unharmed.

In seeking to discover some adequate cause for so great a natural event, one destructive agency, not as yet mentioned, offers itself as a not improbable explanation. It is one neither of inorganic action, of food competition nor of direct assault. On the contrary it is a kind of indirect assault—an assault not on the animals themselves, but on their eggs and young. This destructive influence is one that is very prevalent in the animal world. It is efficient in keeping down the numbers of prolific forms at present, and may have had much to do with the extinction of species in the past. It is a danger to which the mammalia are exposed only in the case of their young, and in this case only to a minor degree, from their vigilant care of their young; but to which the fish, reptiles and birds are exposed in the case of their eggs as well. The evolution of instinct has taught birds to care for their eggs and young, and thus in great measure to escape this peril. In reptiles this instinct of carefulness is very little developed, and in fishes scarcely at all. Fish species, indeed, escape annihilation mainly through fecundity. Though myriads of their eggs and young are devoured, enough escape to ensure the continuance of the species. The reptiles are intermediate between the birds and the fishes in these particulars, less prolific than the latter, less careful than the former. Existing reptiles take little or no care of their young and rarely any special care of their eggs. The turtles conceal theirs very skilfully in the sand and leave them to chance and secrecy for safety; the young, when hatched, being very agile in their escape to the water. But eggs and young alike have their enemies. The former are often discovered and devoured; the latter have numerous foes in and out of the water. Only a mere fraction of the brood escapes to keep alive the species. The crocodile lays its eggs in the warm sand, or in a heap of mud or decaying vegetation, and pays no further attention to them. The alligator is more careful, keeping some measure of watch and ward over its eggs. The existing land reptiles—the snakes, lizards and land turtles—as a rule, pay but little attention to the fate of their eggs and young,

and in many cases leave them largely to chance, their sole trust being in concealment.

The degree of care paid by existing reptiles to the fate of their eggs, small as it is, may have been the result of a long-continued struggle for existence. As the activity and ingenuity of their foes increased, so may have increased reptilian care and fecundity. Probably ages ago both less heed was given to the security of the eggs than now and the peril was less imminent. There has very likely been a campaign of education on both sides. Yet it may be that the continued existence of the modern reptilian families is in a measure due to some degree of care always exercised over their eggs. And it is possible that little care may have been taken by the giant Mesozoic reptiles, and that their extinction was largely due to this cause.

The views here expressed certainly lead us to a fuller comprehension of the situation in which the Cretaceous reptiles were placed. These creatures, large and small alike, were egg layers, and their eggs and young were exposed to the peculiar dangers above indicated. To what extent they took care of their eggs we cannot know, but to judge from the habits of existing reptiles their care was not great. We are aware that these huge creatures possessed very small brains, and must conceive that they possessed little or no intelligence, being governed in great measure by the instincts acquired during past ages of slow development. These instincts were gained at an early period in which the eggs were little exposed to danger and stood in no great need of protection. They were likely to be of little avail in an age in which the growing intelligence of the smaller animals may have greatly increased the danger in this direction.

As regards the great ocean reptiles of the period in question, their vulnerable point was undoubtedly in their habit of egg-laying, since, like their modern representatives, the turtles, they must have laid their eggs on the shores—perhaps with some effort at concealment in the sand—and left them to nature and fortune. The great land reptiles were probably little if any more heedful, if we may judge from the habits of existing land reptiles, whose small degree of care is in part an outcome of later evolution. Again, those huge creatures probably laid but few eggs—certainly much fewer than the smaller animals whose continued existence may be largely due to their

fecundity. In consequence their danger of extinction through the destruction of their eggs was correspondingly increased.

In review of what is above said, it may be remarked that in the early days of reptilian dominance, and of general lack of animal activity and intelligence, the reptilian lords of the earth were exposed to little danger of being devoured in the egg by hungry enemies, and needed little care for eggs and young; the result being that no very marked instinct of concealment or personal supervision became developed. But during the later Mesozoic period, an important change took place in the situation. Ages before the reptiles lost their dominance a new order of beings, the mammals, had come into existence. The ancestors of the mammalia—typified by the modern *Ornithorhynchus*—were themselves egg-layers. Marsupial mammals followed, and continued throughout most of the Mesozoic age. Insignificant in size, and probably as lacking in intelligence as their reptilian competitors, these creatures long contented themselves with gleaning after the great reptiles, with no evidence of ability to compete with them. Finally appeared the placental mammals, whose young were at birth able to take care of themselves. And, with the coming of this animal type the prevailing stupidity began to yield to a mental condition a step nearer intelligence.

The reptiles had hitherto occupied the field, the mammals being helpless against them by any direct methods of assault, while the greater activity of the latter, and the consumption of the bulk of the food supply by the great reptiles, checked any disposition in the mammals to increase in size. It is not unlikely that the newcomers gained the victory at length by the indirect methods indicated, an assault upon the eggs, and perhaps the young, of their powerful rivals.

It is highly probable that the placental mammals, with slowly developing intelligence, adopted, from time to time, new methods of attack; while the reptiles, depending mainly upon previously acquired instincts, were very much slower in developing new methods of defence. The reptiles, therefore, eventually found themselves at a serious disadvantage in competition with their small, active, and more cunning opponents. Contemporaneous with the great reptiles were multitudes of prowling creatures, small and agile, whose growing mental powers gradually made them aware that reptilian eggs were full of savory nutriment, and in time taught them the simple arts of concealment of the sea monsters, and how to circumvent the

watchfulness, if any existed, of the small-brained land giants. The reptilian stream of life, in short, may have been thus assailed with increasing pertinacity and intelligence at its source, the eggs devoured, the young perhaps destroyed, and the numbers of these lords of land and sea rapidly reduced. As Achilles had his only vulnerable spot in the heel, these giant reptiles had theirs in the nest. The egg-destroying mammals had a double advantage. Laying no eggs themselves, and caring for their young, they could only be destroyed when in the mature stage, while their assault upon their foes was by the safer and more effective process of devouring them in the egg—a method which may well have caused rapid reduction in numbers and final extinction. The reptilian forms which continued to exist were likely to be the smaller and more prolific ones, and perhaps those which had developed somewhat efficacious methods of caring for their eggs—methods which may have continued to improve as the mental acuteness of their foes increased.

The ground once cleared by the disappearance of the larger reptiles, the subsequent rapid development of the mammalia is readily comprehensible. They now became the dominant class, and in all ages of geological history each new dominant class has expanded rapidly in numbers, in variety of species, and in life of individuals. They were no longer forced to glean after the harvest of powerful competitors, but had the earth's stores of food for their own, and developed accordingly, the remaining reptiles becoming in their turn the gleaners after the harvest. Not only the land, but the ocean, had lost its masters and become an open field for competition. Its reptilian dynasties, impregnable by direct assault, and having no powerful enemies in their liquid domain, had yielded to indirect attack, and mammalian life quickly overflowed into this great reservoir of food in the form of seals, cetacea, and other air breathing swimmers. The axe had been laid to the root of monster reptilian life, and a new race of lords of the earth succeeded.

To come now to the second instance of extinction alluded to, that of the Post-pliocene, or Recent period, it is one that is, in some of its features, very difficult of explanation. The only general cause that has been adduced for it, that of the intense chill and deep snow-fall of the Glacial Age, in all probability had much to do with it, though certainly not all. As regards the mammoth and the woolly rhinoceros of Europe and Asia, there seems much reason to believe that they

perished from the cold. This seems probable from their high northern range, and the immense store of their remains now existing in northern Siberia, and in the ice-bound Liakhov or New Siberian Islands. A similiar fate may have overtaken the Irish elk, the urus, the mastodon, and other animals, but such was certainly not the case with the American horse, nor with the giant sloths and the glyptodon of South America, animals which became extinct during the same period.

The disappearance of the horse, in America, is an unsolved mystery. This animal extended in range through a double continent, and has left its remains from Alaska to Patagonia. The horse, it is true, is one of the most highly specialized of animals, and thus belongs to the class that is most liable to sudden extinction. But its specialization is not one that confines it within narrow or local limits or to a temporary phase of conditions. It is at home on the firm, grassy uplands, and is unsuited to forest, mountain, or moist lowlands. In the eastern hemisphere the natural habitat of the horse is on the steppes of Asia, while other species of the genus inhabit the plains of southern Asia and of Africa. In the western hemisphere it was probably most abundant on the open plains of central and western North America, and on the great grassy plains of the southern continent. As regards the habitat of the North American horse, it is one that is exposed to snows, frequently severe ones, in the winter season. The same may have been the case in Asia, if the habit of scraping with the fore-feet, which is possessed by the horse, arose, as has been supposed, from an instinct of scraping away the snows to get at the herbage beneath. Despite this instinct, in abnormal winters, many horses must have perished through the depth and persistence of the snows, as many cattle and sheep do now. During the glacial period this condition existed in an exaggerated degree, and may have caused the extinction of the North American horse. Most of its original range was buried under mountains of ice, which persisted for many centuries. South of the ice limit very frigid conditions must have existed, and deep and persistent snows each winter probably covered all the southern regions of the United States and the plateau of Mexico.

Under such conditions the horse might well have become extinct. Many contemporaries, such as the bison, the antelope, etc., could have taken refuge in the forest and swampy regions of the semi-

tropical lowlands; but these were not suitable habitats for the horse, which could only thrive on the firm and grassy uplands, and which may in consequence have become extinct at this time in North America.

This explanation, however, fails to account for the disappearance of the South American horse, or of its huge contemporaries, the megatherium, megalonyx, mylodon and glyptodon. The disappearance of the last named animals, in view of their sluggishness and stupidity, is not inexplicable, since it may have been due to a cause similar to that we have adduced in the case of the cretaceous reptiles—the destruction of their young by more agile and cunning animals. To this it may be objected that in such a case they would probably have disappeared early, and never attained their wide distribution. But this by no means follows. Intelligent animals may rapidly develop new methods of attack. Unintelligent animals are not likely to develop new methods of defence with similar rapidity. If some active carnivorous animal, therefore, began to attack and destroy the young of the giant sloths in a new and covert manner, the parents may have proved quite incapable of guarding against this suddenly developed danger, and the coming generations of these creatures may have been fatally reduced.

We must, however, in considering the problem of the disappearance of the animals in question, take into account a hostile agency which did not exist at any earlier period—that of Man. A new lord of the earth had appeared, and one with powers of destruction never before possessed in the animal world. Within quite recent times several species of animals have become extinct through human aggression. Others may have become extinct in the past. We know that the early savages of Europe killed the horse and other large animals for food, and the early Americans may have done the same. Man may have played an active part in the extinction of the giant sloths and the glyptodon—if they persisted till the human period—by destroying their young, even if he did not attack the mature animals—and have thus cut off these specially dull and slothful species.

Such an explanation will not account for the extinction of the South American horse, nor does any hypothesis—even of an unsatisfactory character—suggest itself. It is true that some entertain the idea that the South American horse did not become extinct.

Not many years after the horse had been introduced into South America by the Spaniards, the crew of a vessel, sailing along the coast, saw a number of horses at a point several hundred miles distant from the small settlements to which horses had been brought from Europe. It is considered questionable that horses which may have escaped from these settlements could have increased in a few years sufficiently to extend several hundred miles away. That the horses thus seen were native animals is possible, though very doubtful, since it seems probable that the native American horse, though of the same species with the European, may have presented some varietal differences in appearance. All that we can say is that this incident leaves the question of the extinction of the South American horse open to some, though a very slight, degree of doubt. If, as is probable, it became extinct, the cause of its extinction must remain an unsolved mystery. In short, the whole subject of animal extinction is one that is rife with difficulties. The best that can be done is to offer some suggestion of causes that may have aided in the disappearance of species: It is quite probable, however, that many influences were at work of which we are ignorant, and most of which will always remain beyond the scope of human investigation or conjecture.