北半球にいた"ペンギンもどき"
3000万年前の化石鳥の謎をさぐる
文=S・L・オルソン／長谷川善和 絵=松岡達堪 訳=中村一恵

巨大な飛べない海鳥の骨が、北米と日本から発見された。その姿形と生態を日米の古生物学者が大胆に復原する。
プロトプテルムの発見

この鳥はウサギやラマのようないくつかの種類に近縁であるが、プロトプテルムの発見は、進化理論の重要な一環となった。これが、まさに進化の流れを示す証拠となった。

歴史的背景

プロトプテルムは、かつては科学者が見逃していたかもしれない種類の化石で、その存在を初めて示唆したのが、1860年代のハンブルク博物館の館長、ロブッターズ・ヨーゼフ・ヘルマンでした。彼は、ある化石集団の中に、鳥の似たもののが含まれていたと発見しました。これが、鳥の進化の重要な一環であることを示唆したのです。

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日本での化石を少し

二、三年にして、長谷川博士は大型の海鳥の化石がさらに日本数所の地点で発見されることを伝えている。私はこれらの標本や化石を産出した地層から赤泥をたどりつき、化石を発見される頃の東京を向かったのである。

長谷川博士と私は奇妙な鳥の化石が産出した北九州市と山口県の何所かを訪れ、歩くべきところを踏んだ後、この北九州市の漁師の家にいたので、私はこの石場で、片斜面の化石を発見するまでには至らなかった。

しかしその後、この探石場はいずれも閉鎖された。しかし、化石が産出している個所のうち一つは採石場である。ここは、海鳥の化石を発見した所である。これらの化石は非常に少なくなかった。

私たちが採集した化石の中には、太田博士の採集した化石があり、その内には太田博士が採集した化石が含まれていた。私たちが採集した化石は、太田博士が採集した化石よりも古いと考えられる。

東京の国立科学博物館に入り、長谷川博士と私はこれまでに採集された化石の標本を調べ始めた。ほとんどの化石が採集された後、さらに地層を調べてみた。この地層は非常に薄いもので、化石を発見することができなかった。

私たちが採集した化石は、太田博士の採集した化石よりも古いものである。この化石は、太田博士が採集した化石よりも古いものである。この化石は、太田博士が採集した化石よりも古いものである。この化石は、太田博士が採集した化石よりも古いものである。
非常に特殊化した翼

オルソンによって最も大型の日本産プロトプテリム類の標本図。プロトプテリム類の大きさをうかがうように、現世のペンギン類中最大の皇帝ペンギンの輪郭図を下に描いた。ペンギンよりも首が長いか、鰭が短い大阪産のオウミガラスのそれについて述べる。これらの翼はおそらく、従来のプロテルム類のものとは大きく異なり、鳥が飛行するための解剖学的特徴を備えていたものである。}

右＝折尾第1柄骨、骨在が観察されたもののほか、採集のときにな破壊を一部受けている。しかし、顎骨の部分が残っていたため、およそその形を復原することが可能であった。中上が右をもとに復原した骨在。白い部分は骨在として母岩に残されていった顎骨から作られた。実際はもう少し長いと思われるかもしれない。扁平な骨在で前部に広いのが特徴である。

中下＝中上に関節する前肢骨、肩胛骨、胸骨と、とりわけ中足骨を短く扁平で、指関節はそれぞれよく発達している。この骨が長い間、研究者を悩ませ、研究の突端となったものである。左＝骨在標本をとんでいる化石。いくつかの化石を研究しているうちに、著者のような発見である。翼の部分と骨在骨、胸骨などである。これらの発見で、体の大きさ、泳ぎ方の問題などを想定できるようになった。
森の蝶ゼフィルス

田中香著 「4,000円」
初夏の森に現われるミドリシキシマ類を知りたくなった時の生活。

動物園の誕生

主な目次：動物園の歴史、動物園の保護、動物園の動物、動物園の動物園。

狩りと人間

主な目次：狩りの歴史、狩猟の道具、狩猟法、狩猟の目的。

家畜のきた道

主な目次：家畜の歴史、家畜の保護、家畜の利用。

ロンドン動物園150年

G.ヴェガーズ著「1,800円」

動物園の季節

中川百合子著「1,200円」

琉球の自然史

木崎正平著「1,400円」
経済の論

プロトペンギン類はどのように分布していたのでしょうか。ジャイアンツペンギンは半球を占めていたと考えられている。しかし、骨格の化石は非常に数が少なく、詳細な解釈が難しく、未だに議論の余地がある。また、古生物学の発展により、新しい解釈が出てきている。これらは、ペンギンの起源と進化についての重要な情報となるだろう。

遺伝の論

ペンギン類の起源は現在も議論の対象であり、特に、半球を占めていたプロトペンギン類の化石が発見されている。彼らの外見は現在のペンギン類と非常に似ているが、骨格の一部は異なる。これにより、ペンギン類の進化が解明される可能性がある。

食品の論

食品の供給源は海洋生物から来ている。特に、魚類は重要な食糧源である。しかしながら、海洋生物の生息状況は次第に悪化している。特に、温暖化の影響により、海水温が上昇していることが問題となっている。

文化の論

文化の発展は人類の進化において重要な役割を果たしている。特に、狩猟と漁業は、人類の食糧確保に大きく貢献している。しかし、これらは自然環境に大きな影響を与えている。

環境の論

環境は人類の生活において重要な役割を果たしている。特に、海洋環境は地球の健康に大きく貢献している。しかしながら、海洋環境が急速に破壊されていることが問題となっている。
THE DISCOVERY OF THE PLOTOPTERIDAE:
GIANT FOSSIL COUNTERPARTS OF PENGUINS FROM THE NORTH PACIFIC

By Storrs L. Olson

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It is very seldom that the opportunity arises to describe an entirely new family of birds representing an altogether unknown lineage. Yet recently for my colleague, Yoshikazu Hasegawa of Yokohama University, and me, just such an opportunity arose through the discovery of fairly numerous fossils, mostly from Japan, of a group of giant seabirds with many of the same locomotory adaptations as penguins. Actually, as I shall relate below, we were not the first to describe this family, but we did have the privilege of being the first scientists to study sufficient numbers of fossils of these birds to be able to ascertain the details of their structure and relationships. The plotopterids, as they are now known, while having the swimming adaptations of penguins, are actually quite unrelated to them and instead belong to the order of birds that includes pelicans, cormorants, anhingas, gannets, and frigatebirds (Pelecaniformes).

The history of this family of birds began with a short two-page scientific note published by Dr. Hildegarde Howard in 1969. Dr. Howard is Director Emerita of the Natural History Museum of Los Angeles County in California, where she has spent many years describing fossil birds. Her short note contained the description of a new species of fossil bird from the San Joaquin Valley of southern California that came from a marine deposit of early Miocene age, about 20 million years old. Dr. Howard had only one end of a coracid of this bird, the coracid being a strong bone in the shoulder girdle of birds that provides a brace between the breastbone and the wing. Yet from this single fragment she deduced that the new bird was related to cormorants and anhingas but had wings used as paddles for swimming, like penguins and auks (Alcidae). She named this bird Plotopterus joquinensis, meaning "swimming-winged bird of the Joaquin Valley", and she created for it a new family, the Plotopteridae.
The significance of this discovery was not understood at the time, and the few people who took any note of it at all probably considered that the specimen was too fragmentary to allow such deductions. As we shall see, Dr. Howard's conclusions were completely substantiated---she had indeed correctly diagnosed an entirely new family of birds from one end of a single bone.

My first acquaintance with the Plotopteridae, although I did not realize it at the time, came in 1973, when Dr. Hasegawa visited the Smithsonian Institution in Washington. He brought with him casts of some fossils of a very large bird from marine deposits in Japan. Because this bird was so large it had first been thought that it might be related to the ostrich-like moas of New Zealand, but when Dr. Hasegawa and I made comparisons with skeletons of existing birds, we found that the foot structure was that of a swimming bird and, in fact, was fairly close to that of anhingas, which are members of the Pelecaniformes but are much smaller and are now entirely restricted to fresh-water. At that time we had only a few fossil leg bones for study, and although we were uncertain of their exact identity, we were sure that they represented a significant new discovery.

Over the next few years, Dr. Hasegawa informed me that additional fossils of large marine birds had been found in several localities in Japan. I decided that I should have some first-hand knowledge of these specimens and the deposits from which they came, so in August 1976 I went to Tokyo to work with my colleagues Dr. Hasegawa and Dr. Hiroyuki Morioka in the National Science Museum.

Dr. Hasegawa and I began by visiting some of the localities in Kyushu and southern Honshu where the strange fossil birds had been obtained. This expedition was purely informative in nature, as we had no expectation of finding any additional bird fossils, and indeed we did not. Two of the fossil sites were in stone quarries, the bones having originally been found by workmen. Both of these quarries had subsequently been abandoned, however, thus greatly reducing the possibility of finding any additional fossils in the future. Another site, which we visited with Dr. Masamichi Ota, now of the Kitakyushu Museum of Natural History, was on Hikoshima Island at Shimonoseki, where Dr. Ota had found a very few bird bones in the sandstone cliffs near the waterline. One of these was a coracoid that provided a crucial link in the development of our knowledge of these birds. On our visit we found only a fossil shark's tooth, but we did get to see the nature of the geological formations in the area.

When we returned to the museum in Tokyo, Dr. Hasegawa and I began examining each of the then known fossil specimens, most of which were bones of the pelvis and hindlimb. But among them was the beautifully preserved complete coracoid that Dr. Ota had collected at Shimonoseki. As I turned it over in my hand, I began to have a feeling of déjà vu. Somewhere I had seen a bone similar to this but much smaller.
Then it occurred to me that in 1974 I had been in Los Angeles and had examined the single specimen of *Plotopterum joaquinensis* described by Dr. Howard. Could it be that these gigantic Japanese fossils were related to the species represented by the little fragment found in California years before? We looked through the National Science Museum for a copy of Dr. Howard's note describing *Plotopterum*, but could not find one, so later Dr. Morioka and I drove to the Yamashina Institute of Ornithology and spent a while searching through unbound journals until we came across the issue in which Dr. Howard's paper had appeared. We were kindly permitted to borrow the journal and returned with it to the National Science Museum. There I compared the photograph of the fragmentary coracid of *Plotopterum* with the complete coracid from Shimonoseki. There could be no doubt that we were dealing with the same family of birds, even though the Japanese specimen was much larger. At least now we had a name for the group we were working with.

We continued to study the fossils in Tokyo for a few days and made careful comparisons of them with skeletons of other groups of Pelecaniformes. It was possible to determine that there were at least four different species included among the Japanese material, all of which differed in size and all of which were much larger than *Plotopterum*, which was about the size of modern cormorants. Some of these species were represented by only a few fragments, however.

Although we had learned a great deal about these new birds, when I left Tokyo to return to the United States, we still did not know what the structure of their wings was like. Because the foot structure was not specialized for diving as in loons and grebes, it seemed quite possible that the wings might have been paddle-like, as Dr. Howard had predicted, but we could not be certain.

Then, on New Year's Day 1977, Douglas Emlong found a partial skeleton of a bird embedded in a boulder of sandstone along the coast of the State of Washington in the northwestern United States. He sent this to the Smithsonian Institution, where it took several weeks to remove the bones from the very hard rock. But as they emerged, I could see that we at last had what we lacked before---wing bones associated with coracoids that definitely belonged to a plotopterid.

These wing bones were quite remarkable. One end of the humerus (the upper arm bone) looked almost exactly like that of flightless auks, whereas the other end looked like that of a penguin. The auks are superficially penguin-like birds of northern seas that are related to gulls and sandpipers but which use their wings for swimming. The newly revealed plotopterid wing was thus seen to be a highly specialized, flattened, paddle-like structure that could not have been used for flying.

Later, Dr. Hasegawa sent me casts of a new specimen of plotopterid from on Ainoshima Island. This is the best specimen yet found and lacks only the head, pelvis, and legs, as the entire vertebral column [actually vertebrae 4 through
as it later proved], sternum, shoulder girdle, and both wings were present and articulated. From this, the penguin-like structure of the wings was particularly evident, yet the breastbone (sternum) was very different and closely resembled that of Pelecaniformes. Only one skull of a plotopterid has been found so far, and this lacks the end of the bill. It too is similar to Pelecaniformes, particularly the gannets (Sulidae), and is not at all like the skull in penguins.

What has been discovered then, is a group of birds with wings like penguins but which are totally unrelated to penguins, having evolved from a different group, the Pelecaniformes. The similarity to penguins in their wings is due to what is called convergent evolution. When unrelated organisms independently evolve similar structures to perform similar functions, this is said to be convergence. For example, porpoises, sharks, and the extinct reptiles called ichthyosaurs, have very similar body shapes and fins, yet they belong to three different classes of vertebrates. Their similarities evolved independently to facilitate passage through water and each group evolved from a very different-looking ancestor. A number of different groups of birds have become adapted for life in water. When a bird moves through the water, it may use either its feet or its wings for propulsion. A few birds, such as shearwaters, use both the wings and the feet. Loons, grebes, cormorants, and the ancient toothed bird Hesperornis are examples of birds that use only their feet for underwater propulsion. Although they are unrelated, each of these groups of birds has striking convergent similarities in the structure of the hindlimb. The pelvis is long and narrow, the femur is short and stout, the tibiotarsus has a long process called the cnemial crest for the attachment of muscles, and the tarsus is flattened so as to offer less resistance in the water. Some foot-propelled diving birds such as the grebe of Lake Titicaca in South America, the Galapagos cormorant, and the fossil bird Hesperornis, have become flightless. In these cases, their flightlessness is due to degeneration of the wings and shoulder girdle, since the wings are no longer necessary for the bird's existence.

Birds that use their wings for underwater locomotion have very different adaptations. The most specialized wing-propelled divers are the penguins, the auks, the diving-petrels of the Southern Hemisphere, and, of course, the Plotopteridae. These birds literally fly through the water. Because the breast muscles provide the propulsive downstroke of the wing, these muscles and the sternum become enlarged relative to those of normal flying birds. The wing must also be raised against water and in penguins is modified to provide propulsive force on the upstroke as well as the downstroke. Consequently the muscles that raise the wing are enlarged and the scapula, where the more powerful of these muscles arise, is enlarged into a very broad, thin blade. In plotopterids the scapula is likewise very broad, unlike any pelecaniform bird.
Nevertheless, the scapula in plotopterids retains a large forward process, the acromion, similar to that in Pelecaniformes, but unlike penguins, in which this process is very reduced. In wing-propelled diving birds, the wing bones become shortened and flattened, and in the more specialized species the bones form a rigid paddle that can no longer function for aerial flight. The flightlessness in these birds (penguins, plotopterids, and a few of the auks) thus evolved in an entirely different manner from that of other flightless birds, and their structure is very different, since the breast muscles are better developed than in flying birds and the wings are extremely specialized, not degenerate.

The plotopterids are particularly curious since they evolved from a group whose members are mostly foot-propelled divers. Anhingas and cormorants, for example, use only the feet for locomotion under water. The gannets and boobies were thought to be mainly foot-propelled divers also. These birds feed by plunging into the water from a height. Recent underwater films show that boobies, after plunging, may use their wings as well as their feet to pursue prey. The ancestors of the Plotopteridae probably started out much the same way, later becoming increasingly dependent on the use of their wings underwater until they ultimately evolved into birds that were superficially more similar to penguins than to the other families of Pelecaniformes.

Penguins are now, and apparently always have been, restricted to the Southern Hemisphere. Numerous penguin fossils have been found, and some of these ancient penguins were gigantic, reaching a maximum standing height of perhaps more than 1.5 meters and a weight of about 135 kilograms. Although the auks can in some ways be regarded as occupying a penguin-like niche in the Northern Hemisphere, most of them are much smaller than any known penguins and none approaches the size of the giant fossil penguins. It was always considered puzzling that there are not true counterparts of penguins or giant penguins in the Northern Hemisphere, but with the new fossils we now see that the Plotopteridae once filled these niches. I have estimated that the largest known plotopterid was probably about 2 meters long from bill tip to tail tip, so that this group of birds could easily have occupied the same kind of niches in the Northern Hemisphere as the giant penguins filled in the Southern Hemisphere.

Why did both the giant penguins and the plotopterids become extinct? All the plotopterid fossils found so far are late Oligocene or early Miocene in age (20 million to 30 million years old). Although younger deposits around the Pacific have been much more extensively studied by paleontologists, no plotopterids have yet been found in any rocks later than early Miocene. This suggests that the family became extinct before the middle of the Miocene, which is about the same time that giant penguins became extinct.

Is it only coincidental that two entirely unrelated groups of birds in different hemispheres died out at the same time? Probably not. For at the same time these diving birds became
extinct, porpoises and seals were undergoing their most intensive period of radiation and diversification. Although it cannot be determined that the ascent of marine mammals was the cause of the extinction of plotopterids and giant penguins, it is a fact that niches for medium-sized, warm-blooded, pelagic predators were occupied by birds in the early Tertiary, whereas from the middle Miocene onward they were occupied by mammals.

This does not mean that the marine mammals simply ate all the birds; more subtle factors undoubtedly were involved. Porpoises, for example, do not have to return to land to bear and raise their young and hence can range farther and would not be as affected by local environmental conditions such as extreme fluctuations in abundance of prey. Birds, on the other hand, are restricted in their choice of nesting sites and must return to land to breed and thus cannot forage as far when feeding young. This would be particularly true of certain flightless seabirds.

There is relatively little that can be said about the behavior and life history of the Plotopteridae. Like most seabirds, they probably nested in large colonies on islands, where they would be protected from predation by terrestrial mammals. One could only speculate on how their courtship and nesting behavior might have been modified by their unique morphology—so different from that of other Pelecaniformes.

Considering that only two plotopterid specimens have been found on the eastern side of the Pacific, the number and diversity of plotopterids recovered in Japan is truly remarkable. Although these birds must once have ranged around most of the North Pacific, for the present it is Japan that is the "home" of the Plotopteridae. Granted that there have been many interesting fossil discoveries in Japan, from my perhaps prejudiced viewpoint there is nothing that compares in interest and significance with the discovery of the Plotopteridae.

With the insight that paleontology provides us, we can now look out over the picturesque coastline of Japan, dotted with islands, and try to envision things as they were 30 million years ago, when similar islands were teeming with great colonies of giant flightless seabirds clambering up rocks and vying with each other for mates and for a patch of ground on which to place their nest. Although the plotopterids are gone forever, we are all a little richer for at least knowing that such remarkable birds once existed.
The following are other references to the Plotopteridae.

Hasegawa, Y. 1978. Nihon ni mo pengin ga ita! [There were penguins in Japan also!]. Kagaku Asahi, 3: 71-75, 8 figures. [In Japanese]


FIGURE CAPTIONS

Slide 1. Cast of the original specimens of Plotopterum joachimensis [sic; this was a lapsus on my part that was carried over to the printed version]. From this small fragment, Dr. Hildegarde Howard correctly diagnosed the new family Plotopteridae. The deductions she made from this little fossil were completely upheld by subsequently discovered, more complete fossils from Japan. Photograph by Victor E. Krantz, courtesy of Smithsonian Institution.

Slide 2. Coracid bones of Plotopteridae showing differences in size. A, a large Japanese species; B, specimen from state of Washington; C, Plotopterum joachimensis. A and B are incomplete. Photograph by Victor E. Krantz, courtesy of Smithsonian Institution.


Figure 1. Dorsal (upper) view of right wing skeleton. A, anhinga (Pelecaniformes); B, great auk (Alcidae, Charadriiformes); C, plotopterid (Pelecaniformes; largest Japanese species; D, penguin (Sphenisciformes). The three birds on the right belong to three different orders and are unrelated, but their wings are very similar because of convergent evolution. The plotopterid (C) evolved from an ancestor with a wing like that of the anhinga (A). Drawn to scale. Drawing by Bonnie Dalzell. From Olson and Hasegawa, 1979.
Figure 2. Anterior (front) view of right tarsometatarsus, the fused bone of the foot. A, anhinga; B, plotopterid, C, penguin. The plotopterid bone, although very stout and heavy, does not look like that of a penguin and is more similar to the anhinga, a member of the Pelecaniformes. Not drawn to scale. Drawing by Bonnie Dalzell. From Olson and Hasegawa, 1979.

Figure 3. The sternum (breastbone) (s) and furcula (clavicles) (f) of the plotopterid from Ainoshima Island. The far forward projection of the keel (c) of the sternum and its solid articulation (a) with the furcula are characteristics of the Pelecaniformes and are totally unlike penguins. Drawing by Bonnie Dalzell. From Olson, 1980.

Figure 4. The scapula (shoulder blade) in an anhinga (A), a plotopterid (B), and a penguin (C). The shoulder blade in the Plotopteridae has become quite broad, as in penguins, but retains the large acromion process (a) typical of Pelecaniformes. Drawing by Bonnie Dalzell. From Olson, 1980.

Large Color Transparency. Artist's reconstruction of what the largest Japanese plotopterid may have looked like in life. The outline below it is that of the largest living penguin, to give some impression of the enormous size of the plotopterid. Painting by Bonnie Dalzell. From Olson and Hasegawa, 1979.