

The *Archaeopteryx* FAQs

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[All About Archaeopteryx](#)

Archaeopteryx is commonly cited as an example of a transitional fossil (i.e. a form showing characters common to two separate groups). This is disputed by anti-evolutionists, who claim that *Archaeopteryx* is a complete bird and thus cannot be transitional. This FAQ briefly describes the fossils and then discusses the large number of features shared between *Archaeopteryx* and dinosaurs. It has been claimed that *Archaeopteryx* could fly just like modern birds. The mechanics of flight are briefly described and it is shown that *Archaeopteryx* lacked features essential to be able to fly like modern birds. *Archaeopteryx*'s ancestry is discussed, along with the contentious position of *Protoavis*.

[On Archaeopteryx, Astronomers, and Forgery](#)

Most anti-evolution arguments about *Archaeopteryx* revolve around how it is a complete bird and thus not transitional. However, a group of people led by Prof. Fred Hoyle and Dr. N. Wickramasinghe have adopted a different tack by suggested that *Archaeopteryx* is a forgery. They claim that the feather impressions were forged onto a small reptile skeleton and implicate the then director of the Natural History Museum in London, Sir Richard Owen. Not unnaturally, these claims have been contested by the Natural History Museum. This FAQ details the claims made by both sides and shows that the suggestion of forgery is unsupported by the evidence.

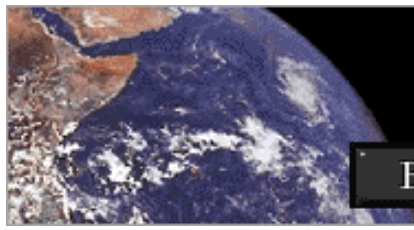
[Archaeopteryx: The Challenge of the Fossil Record](#)

The most detailed anti-evolution claims that have been made about *Archaeopteryx* occur in "Evolution: the Challenge of the Fossil Record" by Dr. D.T. Gish. This book, first published in 1985, is probably one of the best known sources of anti-evolution arguments. It has now been superseded by a new book, "Evolution: The Fossils Still Say NO", published in 1995. However, given the well known half-life of anti-evolutionary material years after it has been superseded, it is useful to look at the claims made in the 1985 book to see whether or not they hold up to scrutiny. They don't.

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Introduction

Archaeopteryx lithographica ("ancient wing from the printing stone").

Named after the limestone in which it was discovered. The stone is a smooth, fine grained limestone which was used in printing. Quarried from in and around the Solnhofen area of Germany. Formed on the bottom of a hypersaline lagoon in the Late Jurassic, about 150 million years ago.

Archaeopteryx specimens

There have been 8 specimens of *Archaeopteryx* found (7 actual specimens and one feather). These finds are documented chronologically (by description) below.

1. The Feather

Found in 1860 near Solnhofen and a revelation when it was described by H. v Meyer in 1861. The surprise was not the age of the fossil, since several ornithopod dinosaur footprints erroneously ascribed to birds were known from the Triassic, but the detail that was preserved.

2. The London Specimen



Found in 1861, near Langenaltheim. Probably the best known (together with the Berlin specimen). Its discovery was announced by H. v Meyer in 1861 and the specimen was subsequently bought by the British Museum of Natural History in London (under the instruction of Richard Owen). It cost 700 UK Pounds - a small fortune in those times, but for that price Owen also received just over a thousand other fossils from Solnhofen. The specimen was sold by amateur collector and local doctor Carl Haberlein, who had received it in lieu of payment for medical treatment. Owen described the specimen in 1863. He saw at once that it was an important find and recognised that it represented a transitional form - but not in the "Darwin" sense. Owen was a staunch "evolutionist", however he did not believe in Darwin's model of evolution. Interestingly Huxley, who **was** a staunch "Darwinist" failed to recognise the true import of the fossil and merely remarked on it as a "reptile-like bird". It wasn't until close comparisons were made with the dinosaur *Compsognathus* that Archae's true worth was realised.

3. The Berlin Specimen



Found in 1877 near Blumenberg. This was a better specimen than the London specimen, principally because it had a complete head, albeit badly crushed, and was snapped up by the Berlin museum. It was sold to them by Carl Haberlein's son (talk about keeping it in the family!). It was described by W. Dames in 1884.

4. The Maxburg Specimen



Found in 1958 near Langenaltheim (same as London Specimen). This specimen is of the torso only and is the only specimen to still be in private hands. In 1992, after the death of its finder and owner Eduard Opitsch, the specimen was found to be missing and it is thought that it was sold secretly (Abbott 1992). It's whereabouts remain unknown. The specimen was described by Heller in 1959.

5. The Haarlem or Teyler Specimen



This specimen was actually found near Reidenburg in 1855, 5 years **before** the feather! It lay in a museum after being classified as *Pterodactylus crassipes* by H. v Meyer in 1875. Curiously, Mayer described it as having a flight membrane unlike any other known pterodactyl, now we know why! A re-examination of the fossil in 1970 by Ostrom revealed feathers and its true identity.

6. The Eichstatt Specimen



Found near Workerszell in 1951, it was described by P. Wellnhofer in 1974. This is the smallest of all the specimens, being some 2/3 the size of the others. It also differs in other aspects such as the tooth structure and the poorly ossified shoulder bones. It has been suggested that this is a separate genus, however the differences can also be ascribed to the possible juvenile stage of the animal and/or a different feeding niche. However, this specimen has the best preserved head, from which the litany of Archae's reptilian cranial features were described. At the moment it still resides within *A. lithographica*.

7. The Solnhofen Specimen



Found in the 1960's near Eichstatt by a Turkish worker. First identified as *Compsognathus*, by an amateur collector, however, further examination showed that the arms were too long for the body size and preparation revealed feather traces. Described by P. Wellnhofer in 1988.

8. The Solnhofen-Aktien-Verein specimen

A new specimen was described by Wellnhofer (1993), but the description is in German and so information is limited. The specimen has been classified as a new species, *Archaeopteryx bavarica*, and has been reported as possessing a small ossified sternum, as well as feather impressions.

Archaeopteryx Features

Much has been made in pseudoscientific circles about the position of Archae within the evolutionary scheme of things. The usual "argument" put forward is that Archae cannot be a transitional fossil between birds and dinosaurs because it is a bird. This simplistic line belies the fact that, whilst Archae is indeed classified as a bird, it has been done so on the strength of 4 main characters - 2 of which are not unique to birds. This classification ignores the fact that Archae has numerous characters which **are** unique, unique in that they are **not** possessed by birds. Archae's avian affinities are allowable on the strength of the following 4 main characters:

Archaeopteryx's avian features

1) Feathers.

Feathers are **the** diagnostic feature of modern birds. This is one of the main criterion for classifying Archae as a bird, as no other modern animal has feathers. The possession of feathers is a characteristic of birds, so strike one up for the birds. **However**, in late 1996, a discovery in China may change this view. A small theropod dinosaur *Sinosauropteryx* (Chen et al. 1998) was found with what appear to be feathers preserved along the back. The identification of the structures is equivocal however, (e.g. Unwin 1998), with some doubting that the structures are feathers.

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Feathered Dinosaurs Found

Two species of dinosaur have recently been found in northeast China which possess feathers (Qiang et al. 1998). *Protoarchaeopteryx robusta* and *Caudipteryx zoui* show regiges, rectrices and plumulaceous feather impressions. Further, they are not birds, lacking a reverted (backwards facing) big toe (see number 2 below) and a quadrate-jugal squamosal contact, having a quadrate-jugal jointed to the quadrate by a ligament and a reduced or absent process of the ishium. These and other characters group *Protoarchaeopteryx* and *Caudipteryx* with maniraptoran coelurosaurs rather than birds.

[Systematics Note (from Padian 1998): Systematists *define* the names of organisms by their ancestry, in this case birds (Aves) consist of *Archaeopteryx* plus living birds and all the descendants of their most recent common ancestor. Birds are *diagnosed* by unique features that only they possess and which are inherited from that common ancestor. Even if feathers are shared by a wider group than just birds, birds are still defined as *Archaeopteryx* and later relatives. *Protoarchaeopteryx* and *Caudipteryx* are not birds even though they have feathers because the suite of morphological characters they possess mark them as belong to the maniraptoran coelurosaur dinosaur.]

It appears that feathers can no longer be used as a unique feature of birds.

For a discussion of the feathered dinosaurs go to [Jeff Poling's Dinosauria page](#).

2) Opposable hallux (big toe).

This also is a character of birds and not of dinosaurs. Although opposable big toes are found in other groups, they are not, as far as I am aware, found in dinosaurs. A reversed big toe is found in some dinosaurs however, and the condition is approached in some theropod dinosaurs.

3) Furcula (wishbone) formed of two clavicles fused together in the midline.

Now we start getting on shaky ground. It used to be thought that the possession of a furcula distinguished birds from dinosaurs. Indeed, up until recently even clavicles were few and far between in even theropod dinosaurs (the suggested closest group to the birds and from which the birds evolved - see Ostrom 1976). However, it has been found that theropod dinosaurs did indeed have clavicles (e.g. Bryant & Russell 1993) and they have been found in several species, e.g., *Segisaurus*, *Velociraptor*, *Euparkeria*, *Ornithosuchus*, *Saltoposuchus*, *Ticinosuchus*. Also, Chure & Madson (1996) reported furculae in a non-maniraptoran, allosaurid dinosaur.

It has been found that the clavicles are often small and poorly ossified. This is no surprise, since they are of little evolutionary advantage to your average theropod dinosaur. However, birds too show this variation in ossification, especially amongst the carnivores and some parrots, clavicles are reduced or even missing. Therefore the apparent absence of clavicles in some theropod dinosaurs may well be due to poor ossification rather than true absence. However, furculas **have** been found in some theropod dinosaurs, namely the Oviraptorosauria (Barsbold *et al.* 1990, Bryant & Russell 1993), for example *Oviraptor* and *Ingenia*. Thus furculas do **not** appear to be diagnostic to birds and certain members of the suggested closest group to the birds now appear to possess furculas so it is a neutral character.

A commonly cited criticism of this is that most of the theropod dinosaurs listed here post-date Archae. However, none of these is claimed as the ancestor anyway, and *Euparkeria* is a Triassic form. The presence of clavicles shows that this character is a feature of theropod dinosaurs and thus was probably present in early theropods.

4) Pubis elongate and directed backward.

This is a feature of birds, but it is also a feature of some theropod dinosaurs so is not diagnostic of birds - another neutral character. However, the pubic shafts of *Archaeopteryx* and dromaeosaurs (a group of theropod dinosaurs which are thought to be closely linked to birds) share a plate-like, slightly angled transverse cross-section which not found in any other archosaurs.

Archaeopteryx's reptile features

5) Premaxilla and maxilla are not horn-covered.

This is posh talk for "does not have a bill." The premaxilla does not have a keratinized covering, so *Archaeopteryx* has no bill. The bill is produced via the process of 'cornification' which involves the mucus layer of the epidermis (Romanoff 1960) and thus its formation is independent of jaw bone formation.

6) Trunk region vertebrae are free.

In birds the trunk vertebrae are always fused.

7) Bones are pneumatic.

I.e. they appear to have air-sacs, as they do in birds and in some dinosaurs (e.g. Witmer 1990, Brooks 1993). It should be pointed out that previous claims suggesting the bones of Archae were not pneumatic (Lambrecht 1933; de Beer 1954), was based on negative evidence, i.e. that the bones do not exhibit pneumatic pores (through which the air sacs enter the bones) and the bones show none of the plumpness and bulges which characterise the pneumatic bones of modern birds. Britt et al. (1998) found evidence for the presence of pneumatic bones in *Archaeopteryx*:

"Here we re-examine two specimens of *Archaeopteryx*. These specimens show evidence of vertebral pneumaticity in the cervical and anterior thoracic vertebrae, thus confirming the phylogenetic continuity between the pneumatic systems of non-avian theropods and living birds" (Britt et al. 1998, p. 374)

8) Pubic shafts with a plate-like, and slightly angled transverse cross-section

A Character shared with dromaeosaurs but not with other dinosaurs or birds

9) Cerebral hemispheres elongate, slender and cerebellum is situated behind the mid-brain and doesn't overlap it from behind or press down on it.

This again is a reptilian feature. In birds the cerebral hemispheres are stout, cerebellum is so much enlarged that it spreads forwards over the mid-brain and compresses it downwards. Thus the shape of the brain is not like that of modern birds, but rather an intermediate stage between dinosaurs and birds (e.g. Alexander 1990).

10) Neck attaches to skull from the rear as in dinosaurs not from below as in modern birds.

The site of neck attachment (from below) is characteristic in birds, *Archaeopteryx* does not have this character, but is the same as theropod dinosaurs:

"Notice that this coelurosaurian-like neck extended back from the rear of the skull in *Archaeopteryx* - as it does in coelurosaurs [theropod dinosaurs], rather than from beneath as in later birds." (Ostrom 1976, p. 137).

Skull and brain of Archae is basically reptilian and is not "totally birdlike" (contrary to a certain creationist's claim).

11) Center of cervical vertebrae have simple concave articular facets.

This is the same as the archosaur pattern. In birds the vertebrae are different, they have a saddle-shaped surface:

"The most striking feature of the vertebrae is the simple disk-like facets of their centra, without any sign of the saddle-shaped articulations found in other birds" (De Beer 1954, p. 17).

12) Long bony tail with many free vertebrae up to tip (no pygostyle).

Birds have a short tail and the caudal vertebrae are fused to give the pygostyle.

13) Premaxilla and maxilla bones bear teeth.

No modern bird possess teeth (e.g. Romanoff 1960; Orr 1966, p. 113). Bird embryos form tooth buds, but do not actually produce teeth. Some birds subsequently produce ridges in the bill, but there is no connection between them and the embryonic tooth buds, since the ridges also form in other areas of the bill where no tooth buds have previously formed. Some birds produce hook-like structures which are papillae, and appear to be related to the process of keratinization of the beak (Romanoff 1960), and have nothing to do with teeth. They do not possess blood vessel or nerve connections, nor do they produce dentine.

The expression of tooth buds in the bird embryo has a simple evolutionary explanation, since it suggests that the ancestors of modern birds possessed teeth and that this character has been suppressed in modern birds. The presence of tooth buds in the embryos of organisms which do not possess teeth in the adult is a difficulty for anti-evolutionists, since why should a character be expressed that is never used in the organism? Some fossil birds exhibit a reduction in the number of bones which have teeth. Both *Hesperornis* and *Baptornis* lack teeth on the premaxilla (*Archaeopteryx* and theropod dinosaurs have teeth on both the maxilla and premaxilla). Not only that, *Hesperornis* has a beak, but on the upper jaw only (Gingerich 1975). It therefore has **half** a beak **and** teeth. A good example of a morphologically intermediate structure between toothed birds which lack a beak, and beaked, toothless birds.

14) Ribs slender, without joints or uncinate processes and do not articulate with the sternum.

Birds have stout ribs with uncinate processes (braces between them) and articulate with the sternum.

15) Pelvic girdle and femur joint is archosaurian rather than avian (except for the backward pointing pubis as mentioned above).

Here Archae really shows its transitional nature. Whilst the pelvic girdle as a whole is basically free and similar to archosaur girdles, the pubis points backward - a character shared with birds and some other bird-like theropod dinosaurs.

What **is** interesting is that with the bird pelvis:

"The ischium lies beneath the posterior part of the ilium and beneath this again is the pubis, which is directed backwards (i.e. like this: =). Embryological studies show that the peculiar position of these bones is the result of secondary rotation and that the pectineal process, in front of the acetabulum, is not the true pubis as some workers have maintained." (Bellairs & Jenkin 1960, p. 258).

In other words, the embryonic pelvis of the bird, when first formed, looks, in shape and angle between the ilium and the pubis (45 degrees), very similar to the "A"-frame pelvis of *Archaeopteryx* (i.e. like this: <) (e.g. Romanoff 1960). The fully formed pelvis with all bones lying parallel is the result of secondary rotation of the pubis from "<" to "="". This supports the view that birds had an ancestor with a saurischian pelvis such as the type possessed by *Archaeopteryx* and other theropod dinosaurs. (see also [A tale of two pelvises](#) below)

16) The Sacrum (the vertebrae developed for the attachment of pelvic girdle) occupies 6 vertebra.

This is the same as in reptiles and especially ornithipod dinosaurs. The bird sacrum covers between 11-23 vertebrae! So, while the variation seen in modern birds is large, it is nowhere near the number found in *Archaeopteryx*

17) Metacarpals (hand) free (except 3rd metacarpal), wrist hand joint flexible.

This is as in reptiles. In birds the metacarpals are fused together with the distal carpals in the carpo-metacarpus, wrist /hand fused. All modern birds have a carpo-metacarpus, all fossil birds have a carpo-metacarpus - except one (guess! :-). However, the carpals of several coelurosaur dinosaur groups show a trend towards fusion, and in the Late Cretaceous form *Avimimus*, a true carpo-metacarpus is formed.

It has been suggested that the ostrich and/or other [Ratites](#) also possess unfused wrist/hand bones. This is not correct:

"The ostrich, emus, rheas, cassowaries and kiwis are often referred to together as the Ratites, though they may not be closely related to each other. They have tiny wings and cannot fly, but the bones of their hands are fused together in the same peculiar way as in flying birds, which suggest that they evolved from flying birds." (Alexander 1990, p. 435).

Some similarity between the hand of the ostrich and some of the more derived theropod dinosaurs was once used to suggest that the Ratites were 'primitive' and evolved before the advent of flight in birds. However Tucker (1938b) showed that such similarities are entirely superficial.

"He has directed attention to the bird-like characters of the hand of the dinosaur *Ornitholestes* as evidence that a bird-like hand can be developed independantly of flight, but the writer has pointed out in the communication mentioned above [Tucker 1938b] that the resemblance is utterly superficial and that the peculiar bowing and terminal fusion of metacarpals 2 and 3 which characterise both the Carnate and the Ratite hand are in no wise [sic?] reproduced in the dinosaur." (Tucker 1938a, p. 334).

"Reverting now to the reasons on which have sought to base the view that the Ratites were primitive birds whose ancestors had never flown, one: the similarity between the hand of the ostrich and that of the dinosaur, has been dismissed as invalid. Tucker (1938b) has shown that such resemblances as there are between them are only superficial and without significance." (de Beer 1956, p. 65).

18) Nasal opening far forward, separated from the eye by a large preorbital fenestra (hole).

This is typical of reptiles, but not of birds. Where a fenestra is present in birds, it is always greatly reduced, and is involved in prokinesis (movement of the beak)

19) Deltoid ridge of the humerus faces anteriorly as do the radial and ulnar condyles.

Typical of reptiles but not found in birds

20) Claws on 3 unfused digits.

No modern adult bird has 3 claws, nor do they have unfused digits. The juvenile hoatzin and Touracos do have 2 claws but loose them as they grow, the ostrich appears to retain its 2 claws into adulthood, due to the early termination of development (see section on [Ratites](#)). In the case of the hoatzin it is thought that these claws allow the juvenile to climb. It had been claimed that since these birds do have claws, even in the juvenile stage, then the presence of claws cannot be used as a reptilian character. This is not so, however. In fact almost all birds exhibit claws, but in the embryonic stage and they are lost by the time the bird leaves the egg. In the case of the few which do retain claws into the juvenile stage, this is merely the extension of the condition into the post-embryonic stage. As McGowan (1984, p 123) says:

"In retaining a primitive reptilian feature which other birds lose just before leaving the egg [the hoatzin] is showing us its reptilian pedigree. Far from being evidence to the contrary, the hoatzin is additional evidence for the reptilian ancestry of birds."

21) The fibula is equal in length to the tibia in the leg.

This again is a typical character of reptiles. In birds the fibula is shortened and reduced.

22) Metatarsals (foot bones) free.

In birds these are fused to form the tarsometatarsus. However, in modern bird embryos, the foot bones are initially separate as in the adult *Archaeopteryx* and is another character supporting a reptilian ancestry for birds. After all, why bother producing separate bones in the embryo and then fuse them? Why not produce a fused mass to start with? No adult modern bird has separate metatarsals, but they are separated, initially, in the embryo. This can be explained in terms of evolution - birds evolved from a group which had

unfused metatarsals.

Ceratosaurs, *Avimimus*, and Elmsauridae all show true tarso-metatarsi. Archae itself only shows the beginning of this structure.

23) Gastralia present.

Gastralia are "ventral ribs," elements of dermal bone in the ventral wall of the abdomen. Typical of reptiles, they are absent in birds, e.g.:

"In addition to the true ribs the British Museum specimen shows a large number of so-called ventral ribs or gastralia, elements of dermal bone lying in the ventral wall of the abdomen." (De Beer 1954, p. 18)

"The gastralia of the Berlin specimen are identical with those of the British Museum specimen, but more have been preserved." (De Beer 1954, p. 19)

"The "new" specimen was found 8 September 1970 on display in the Teyler Museum, Haarlem, Netherlands. It consists of two small slabs (specimens 6928 & 6929), part and counterpart which contain impressions or parts of the left manus and forearm, pelvis, both legs and feet, and some gastralia." (Ostrom 1970, p. 538)

"Also present are numerous fragments of gastralia, faint impressions of three or four dorsal vertebrae, . . ." (Ostrom 1972, p. 291).

"The counterpart slab (No. 6929) contains additional gastralia, phalanges, .." (Ostrom 1972, p. 291)

"Gastralia, or dermal abdominal ribs are present in all five skeletal specimens of *_Archaeopteryx_*" (Ostrom 1975, p. 139-140).

Gastralia are present on the Eichstatt specimen (See Wellnhofer 1974, fig. 7C)

Table of archaeopteryx features

1 = present; * = present in some; ? = possibly present; x = absent

	Dinosaurs	Archae	Birds
1	*	1	1
2	x	1	1
3	*	1	1
4	*	1	1
5	x	x	1
6	x	x	1
7	*	x	1
8	*	1	x
9	1	1	x
10	1	1	x
11	1	1	x
12	1	1	x
13	1	1	x
14	1	1	x
15	1	1	x
16	6	6	11-23
17	1	1	x
18	1	1	*
19	1	1	x
20	1	1	x
21	1	1	x
22	1	1	x
23	1	1	x

It can be seen that Archae possesses many more characters which are present in dinosaurs and **not** in birds, than it does characters which are present in birds but not in dinosaurs. This is why Archae is a true transitional species, because it shares some characters which are diagnostic of one group whilst still retaining characters diagnostic of its ancestral group. Anyone who claims that Archae is 100% bird is wrong. Anyone who claims that Archae's skeleton is even predominantly bird-like is wrong. Anyone who claims Archae has a "totally birdlike" skull is wrong.

This latter point is made in reference to the claim by Dr. Duane Gish that the skull of Archae is "totally birdlike" (R. Trott pers. comm. 1994). This claim is false. To show this we need to consider the skull of Archae further.

Cranial features of Archaeopteryx

As stated above, Dr Gish claims that the skull of Archae is "totally birdlike." This is false. Romer (1950 p. 261) describes Archae thus: "The skull, as far as can be seen, was rather birdlike. . . ." However, not only is this a far cry from "totally birdlike," but Romer was using the detailed reconstruction of the Berlin Specimen, by Heilmann (1926). Ostrom (1976 p. 131) has this to say on the Heilmann reconstruction:

"Despite the details shown there [Heilmann's reconstruction of the skull -cn], the actual specimen does not permit such detailed and precise conclusions. It [the Berlin specimen's skull - cn] is badly crushed and the bones are extensively fracture, chipped and distorted - to the extent that very few cranial or mandibular sutures are unmistakably identifiable. Heilmann's

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reconstructions have been republished by many authors and subsequent interpretations and hypotheses based on it. Quite probably, some authors have been unaware of the inadequate basis of Heilmann's reconstruction, and understandably so unless they have had the opportunity to examine the specimen itself."

And again on the same page:

"Fortunately, the Eichstatt specimen now provides a comparative basis for evaluating and correcting past reconstructions of the Berlin skull."

As mentioned above, the Eichstatt specimen was not described until 1974, therefore Romer's description was based on the Heilmann reconstruction.

Using both specimens, Ostrom (1976 p. 132) delineated 10 characters on the skull of Archae which it shares with other theropod dinosaurs such as *Ornitholestes*, *Compsognathus*, *Velociraptor* and perhaps *Saurornithoides*. These are:

1. A sharply tapered snout. In birds the maxilla makes up the "snout". Although the snout is shortened in Archae.
2. Long elliptical external nares [nostrils] bounded almost exclusively above and below by the premaxilla and nasal (a bone at the front of the upper jaw). In birds the nares are reduced and removed posteriorly (closer to the eyes) due to the increase in size of the premaxilla.
3. A large preorbital fossa and a large triangular postorbital fossa which contains two small openings. (These are holes in the skull. One is a single opening in front of the orbit or eye socket, the other is behind the eye socket and has two openings). In other fossil birds the preorbital is reduced, the postorbital has only a single opening. In modern birds the preorbital is greatly reduced and the postorbital has a single opening.
4. A slender, nearly vertical preorbital bar separating the antorbital fossa and the orbit (There's that hole again! This means that there is a vertical bar of bone separating the hole in front of the eye with the eye itself). Fossil and modern birds have a much more robust preorbital bar - due to the reduction of the preorbital fossa.
5. A large circular orbit which contains a large sclerotic ring. (The sclerotic ring is common to reptiles, birds and actinopterygian fish, but most fossil reptiles and all fossil birds have them. They are a series of ossified plates which circle the eye).
6. A thin, straight jugal bone makes up the zygomatic arch (this is the bone that runs under the eye, the cheek-bone as it extends back towards your ear, in humans). In modern birds the arch is composed of the quadratojugal, jugal and maxilla bones.
7. A stout quadrate of moderate length which is inclined forward. This is the bone in the upper jaw which forms part of the jaw articulation - with the articular - in reptiles, and Archae has a big one, um if you see what I mean! (Incidentally - for those of you who are still with us, the quadrate is attached to the stapes in the upper jaw, and as we all know, the stapes is the bone which vibrates in the ear so that we can all hear. Thus the stapes and quadrate were attached in reptiles and it is not a great leap forward to have both the stapes and the quadrate in the ear as it is in mammals. Thus the claim made by Gish that - in order for the bones to enter the ear in the transition from reptiles to mammals they would have had to go through a stage whereby the 'mammal' would have deafened itself every time it opened its mouth - is not accurate, since the condition of stapes+quadrate articulating in the jaw joint **is found in fossil and extant reptiles**, but I digress.)
8. A lower jaw which is unusually shallow and has a conspicuous bend behind the tooth row. Not in birds.
9. A long retroarticular process. Again a classic reptile jaw-joint feature, but shared with birds.
10. Premaxilla, lacrimal and jugal bones separate. In birds the premaxilla bone is connected to the jugal bone; the jugal bone is connected to the lacrimal bone. . . :-)

Recently Elzanowski & Wellenhofer (1996) have highlighted some more similarities between the skull of *Archaeopteryx* and those of theropod dinosaurs:

A single vomer.

Strong curvature of the ectopterygoid hook.

A dorsal recess in the prootic.

Although *Archaeopteryx* does have certain skull characters which are avian, these are insufficient to allow the characterization "totally birdlike".

Heilmann described an external mandibular fenestra (a hole in the lower jaw) bordered below by the dentary bone - which is the condition in birds - rather than by the angular bone - as it is in reptiles. This would indicate that Archae has a lower jaw which contained both avian (said mandibular fenestra) and reptilian features (toothed lower jaw). This is all very well and dandy and is a feature which one would like to see in Archae. However, as Ostrom (1976 p. 132) points out:

"Much as I would like to accept this interpretation, the highly fractured condition of the lower jaw bone (or bones) that border the supposed mandibular fenestra, either below or above, make it impossible to certify their identifications. In fact, the fractured upper margins of the supposed fenestra leave considerable doubt as to the very existence of a 'fenestra' - a doubt which has not been removed by the Eichstatt specimen." Thus, far from conspiring to present Archae in the best possible light, a very useful feature which would have aided in the description of Archae as a true transitional fossil has in fact been shown to be, in all probability, not true. So much for the evolutionist conspiracy! Indeed the seventh specimen shows that a mandibular fenestra is absent (Elzanowski & Wellenhofer 1996)

Another important feature of the skull of Archae is the occipital condyle and the foramen magnum. In Archae these are well above the dorsal end of the quadrate. As Ostrom (1976 p. 136) writes:

"This primitive condition is characteristic of both pseudosuchians and theropods, in contrast to all later birds where the occipital condyle and foramen magnum are at the base of the skull, well below the level of the upper extremity of the quadrate. In this feature, *Archaeopteryx* was far from avian."

Whetstone (1981, p. 449) does describe the **braincase** (as opposed to the **skull**) of *Archaeopteryx* as, "typically avian", however, he also describes skull features found in *Archaeopteryx* and not in birds.

More recently there has been some conjecture as to the structure of the quadrate bone in Archae. The quadrate from the Eichstatt specimen was described as being single headed - i.e. the top of the quadrate has only one rounded knob which articulates with the skull in only one place. In all modern birds, the quadrate is double headed - i.e. the top of the quadrate has two rounded knobs and therefore articulates with the skull in two places. Based on computer tomography a buried portion of the skull of the Eichstatt specimen, Haubiltz et al. (1988) suggested that Archae possessed a double headed quadrate. However, the image is poor and the presence of another bone underlying the quadrate cannot be ruled out. The only quadrate found in place in any specimen is single headed and a similar bone from the London specimen which appears to be the quadrate, is also single headed. Identification of the quadrate in the seventh specimen has confirmed that the bone was single headed (Elzanowski & Wellnhofer 1996). Thus the quadrate of Archae appears to be reptilian and not avian.

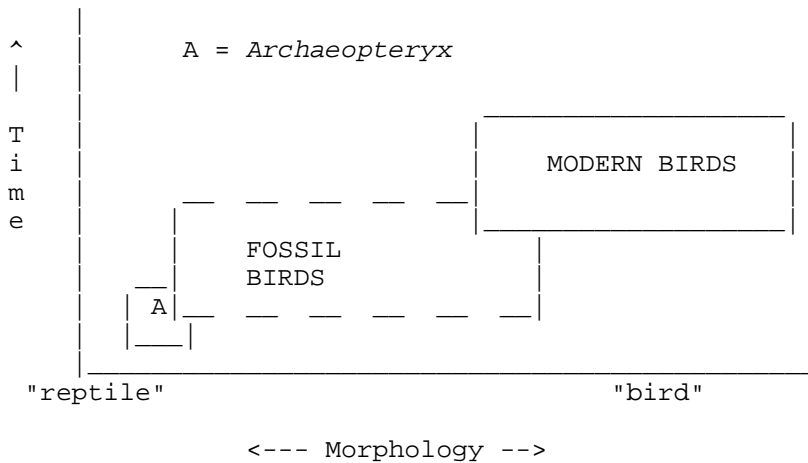
As can be seen, Archae's skull is not "totally birdlike." The "totally birdlike" claim is without foundation.

One is that the differences seen between *_Archaeopteryx_*, fossil birds and modern birds can be explained as just variation within birds. Allied to this is the claim that some modern birds (Ratites) share a number morphological features with *_Archaeopteryx_*.

Archaeopteryx+ modern birds, just variation within kind?

It has been suggested that the differences between *Archaeopteryx* and modern birds represents simple within-group variation. However, this is not correct. Modern birds show a large number of derived morphological characters not possessed by *Archaeopteryx*. Morphologically, *Archaeopteryx* clearly appears more closely related to theropod dinosaurs than any other group and is grouped with birds over theropod dinosaurs due to the possession of only two main characters, presence of feathers, and presence of a fully reverted hallux (toe).

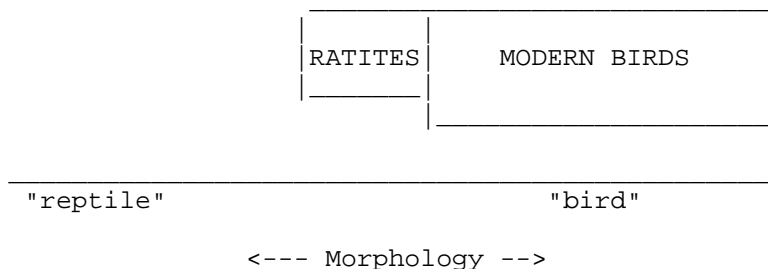
The relevant morphological variation can be represented graphically (if crudely) in the following figure:



As can be seen, the variation within birds shows a distinct trend. The more "reptile"-like morphologies occur in the earliest birds, with the typical 'modern' bird morphology restricted to later birds. If, as suggested, morphological variation is simply variation within birds, we would expect to see the various morphological groups (fossil birds, modern birds) evenly spread throughout the relevant time interval. If, however, birds evolved from theropod dinosaurs, then we would expect to see the first birds to possess more "reptile"-like characters and the more derived, modern birds to have less "reptile"-like characters. This, in fact, is what we see. Thus the distribution of characters within birds supports their derivation from theropod dinosaur ancestors and does not support the claim that variation is simply 'within kind'.

Ratites

Much is made of the morphological features of the Ratites (ostriches, kiwi's etc.), and superficially it may seem that these birds support the 'variation within kind' suggestion as the following figure shows:

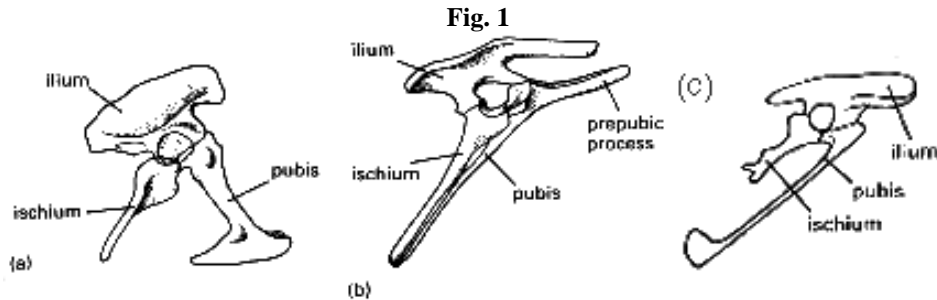


Importantly however, other morphological characters possessed by Ratites clearly show that they are derived from a modern, flying bird morphology and thus the Ratites are actually neotonous on modern birds, with their more "reptile"-like characters due to the early

termination of development, leaving them with some morphological characters similar to *Archaeopteryx* and some fossil birds (see [below](#)). These characters are developmental and therefore provide further supporting evidence for a theropod dinosaur-bird link.

A tale of two pelvises

Dinosaurs can be divided into two groups based on the shape of the pelvis. The Saurischia, or 'lizard hipped' dinosaurs, and the Ornithischia, or 'bird hipped' dinosaurs. Strange as it may seem, *Archaeopteryx* and all modern birds are thought to have evolved from the Saurischia, not from the bird hipped, Ornithischia! Odd? Well, not really. The pelvises in question are shown in Fig.1.



The saurischian pelvis (Fig.1a) is the more primitive structure, and has the pubis pointing forwards and the ischium backwards. In ornithischians (Fig. 1b), the pubis runs back in parallel with the ischium. Additionally, a prepubic process is present, which is assumed to have been used as a point of muscle attachment in the absence of the pubis (probably to support the gut). This situation is superficially similar to that in birds (hence the name 'bird hipped' - the pelvis of birds was well known to anatomists by the time dinosaurs were being described). However, on closer examination, clear differences are evident. In *Archaeopteryx* (Fig. 1c) and all birds, the prepubic process is absent and, unlike in saurischians, the pubis do not meet along the midline. Also, in *Archaeopteryx* the pubis still maintains the club-like termination, as in many saurischians. It should also be noted that several saurischian dinosaurs have the pubis facing backward, e.g. *Troodon*. The pelvis of *Archaeopteryx* is morphologically intermediate between saurischian dinosaurs and birds.

But why did this occur? Well, the primary thrust generator in earlier theropods was the Caudofemoralis longus, which stretched from the leg to some distance along the tail. Later forms such as the dromaeosaurids (the group closely related to *Archaeopteryx*) rearranged this so that the primary thrust was produced by muscles attaching from the leg to the pelvis and the base of the tail. This allowed the tail to be braced and used as a stabilizing device, such as in allosaurs and 'raptors', or to be lost as in modern birds.

In ornithischians the backwards pointing pubis probably occurred to allow for the expansion of the stomach and gut in order to better digest plant material.

Study of the embryonic development of the modern bird pelvis is also instructive. The embryonic pelvis in modern birds starts out in a very similar configuration to *Archaeopteryx*, with the ilium and pubis bones set apart at an angle of approx. 45 degrees. The embryonic bones then secondarily rotate through angles seen in modern [Ratites](#) until reaching the parallel alignment typifying adult, modern birds (see Romanoff 1960, p. 1010):

Chicken embryo	Angle ilium-pubis	Adults with same angle
7.0 days	45 degrees	<i>Archaeopteryx</i>
7.3 days	35 degrees	Kiwi
8.0 days	30 degrees	Ostrich
Hatching	<5 degrees	Modern chicken

The angle between the ilium and the pubis bones in the pelvis of modern Ratites is intermediate between *Archaeopteryx* and modern birds, as would be expected if:

- Modern birds are descended from reptile-like ancestors similar to *Archaeopteryx*
- Ratites are neotenuous descendents of flying birds, in which development has been halted prematurely.

To fly or not to fly

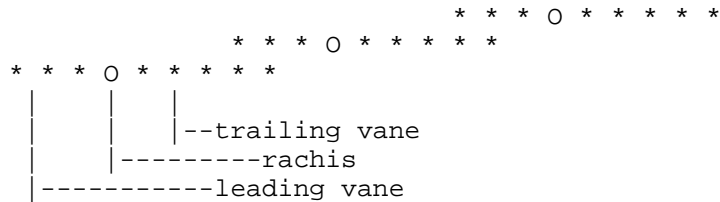
Flying is a tricky business. However, flying confers such a strong evolutionary advantage that it is not surprising that the ability has evolved several times. The success of birds provide ample evidence for the positive benefits of flight. If it did fly, *Archae* must have utilized much the same method as do birds today, therefore a discussion on the possibility of flight in *Archae* must consider those structures most relevant to flight in birds. These are the feathers, the flexibility of the wing, muscle bulk and the presence of a keeled sternum.

Feathers

Feathers are composed of a long, tapering, central rachis, which bears closely spaced side branches called barbs. The barbs on either side of the rachis constitute a surface called the vane. The two vanes on the feather may be symmetrical (i.e. the same width) or asymmetrical, in which case the rachis appears closer to one edge of the feather than the other. The flight feathers of modern birds are typically asymmetrical, whilst body contour and semiplume feathers are symmetrical.

In modern birds, remiges, or wing feathers, are highly modified for power flight (e.g. McFarland et al. 1985), primarily in that the rachis is shifted towards the leading edge of the feather (i.e. the leading vane is thinner than the trailing vane), resulting in an asymmetric feather. The thinner or leading vane of the feather overlaps the wider or trailing vane of the feather in front of it (Fig. 2). The trailing vane contains zones of friction barbules which grip the overlapping feather and stop the feathers from slipping too far apart.

Fig. 2



Speakman & Thomas (1994) compared the asymmetry of some of the flight feathers of Archae (flight feathers 4, 5 and 6) with those of modern flying and flightless birds and the isolated feather from Solnhofen. They found that the average asymmetry for Archae feathers was 1.25, which was lower than that of modern flying birds (lowest around 2.2), but which overlapped that of modern flightless birds. The isolated feather exhibited an asymmetry of 2.2 - just within the range of modern flying birds. However, it is not known whether this feather is from Archae, or where on Archae the feather was situated if it is an Archae feather. Norberg (1995) correctly pointed out, that the curvature of the feather is also important in flight ability, and Archie's feathers exhibit significant curvature. It appears as though Speakman & Thomas may have measured the wrong feathers however. Paul Davis (pers. comm. 1996) has pointed out that Speakman & Thomas appear to have numbered the primary feathers starting at the wing tip and moving towards the body, whereas current practice is to number the feathers starting from the body and moving outwards along the wing (e.g. Rietschel 1985). This is important, since the asymmetry of feathers decreases towards the wing tip - thus Speakman & Thomas appear to have measured the feathers with lower asymmetry. Measurements of the higher asymmetry feathers close to the body yield a value of around 2.32 - which overlap the lower range for extant flying birds (e.g. Norberg 1995; P.G. Davis pers. comm. 1996). The first flight feathers of birds are always highly asymmetric however, and so this result is equivocal. The bulk of the flight feathers on Archae appear to have a slightly lower asymmetry than that found in flying birds today. In reality however, feather asymmetry is a bit of a red herring when it comes to flight capability. Feathers are asymmetrical to maintain aerodynamic integrity as they deform under aerodynamic loads in flight, and thus the greatest asymmetry occurs in birds in which such loads are greatest - i.e. birds with high manoeuvrability and climbing flight (J.M.V. Rayner, pers. comm. 1995). Thus asymmetry is a derived condition for a derived flight capability - one *Archaeopteryx* never possessed. Thus it is not surprising that *Archaeopteryx* possessed low asymmetry feathers, but this does not preclude *Archaeopteryx* from flying.

Wing flexibility

Consider the carniate [birds with a keeled sternum] wing. A marvel of adaptation, well able to sustain quite large animals in power flight for long distances. But what is it about the anatomy of the wing that allows the possibility of flight? Well simply put, 'it's all in the wrist action.'

In modern birds the shoulder joint acts as a universal joint, with a high degree of mobility not only adduction [wing movement down], abduction [wing movement up] and extension [extending wing away from body] and retraction [pulling wing into body], but also significant rotation along the long axis of the humerus.

The elbow, by contrast, is a very restrictive joint. It only allows planar extension and flexure [in other words unfolding and folding of the wing - i.e there is no rotational component.

However, it is the wrist joint which is important. The wrist is composed of two bony carpals which control the movement of the joint. Distally beyond this is the fused carpometacarpus - produced from a fusion of the remaining carpal [wrist] bones and the metacarpal [lower hand] bones. Beyond that is the sometimes incompletely fused manus composed of three digits. This complex, distal of the wrist joint, comprises a near-rigid platform for the attachment of the primary remiges [flight feathers], the secondary remiges attach to the forearm.

The configuration of the wrist joint, articulating as it does on two small, round carpels, allows an amazing range of movement. To demonstrate this you need to be sitting comfortably at the computer terminal. Extend your arms as if you were about to type (palms down, hairy bits up). Now, rotate your hands so that the palms are facing up (as if you are carrying something). This rotation is carried out by the wrist joint in birds. Note that in humans, this action is carried out by rotation of the forearm and not the wrist. Now, return the hands to the hairy bits up position and rotate the hands so that the palm faces the computer (the universal "stop" sign) and rotate the hand down until the hairy bits point to the computer. This rotation is carried out by the wrist joint in birds, as it is in humans.

As you have now demonstrated, the carniate wrist is much more flexible than the human wrist (you have also demonstrated to any co-worker watching that you are insane and in dire need of a holiday!). This flexibility is vital to powered flight, since it allows the wrist/hand to describe a lazy figure-of-eight during a complete flap. Remember that the elbow joint allows no rotation, but the wing must be able to present a solid open wing on the down (power) stroke, but be able to rotate the wing during the recovery (up) stroke to minimise resistance. The birds accomplish this by rotating the wrist and shoulder.

At the top of the power stroke, the wrist is orientated to present the maximum surface area to the air (palm facing downward). During the power stroke, the wrist and hand describes an "S", or two arcs representing the left hand side of the upper loop and the right hand side of the

lower loop of an "8". At the bottom of the power stroke the wrist and hand is at the bottom of the "8". During the start of the recovery stroke the wrist reorients 90 degrees, thus presenting the minimum surface area to the air. The wing then completes the "8" by describing the left hand side of the lower loop and the right hand side of the upper loop. It is easier to perform than to read. Hold your right arm out horizontally from the shoulder, with the palm pointing downwards. Lock the elbow so that you cannot bend the arm, only rotate it. Now the power stroke is an "S" shape, keeping the palm pointing downwards and the elbow locked. At the bottom of the "S", rotate the palm 90 degrees until it is pointing forwards (actually you will have to rotate your whole arm to do this, in birds it is done by the wrist joint). Now, the recovery stroke is a mirror image "S", completing an "8", as you reach the top of the stroke the palm should twist back to point down again and you are ready for the power stroke. Repeat a few times until you get the feel of it or until someone sends for the guy's in the white coats. That is how birds can fly and, hopefully, you can now see the importance of having a flexible wrist joint.

One last important point in this bit. Folding of the wing occurs by contraction of the M. biceps brachii, which is attached to the ulna. This movement automatically folds the metacarpus and hand downward and inward, so that folding at the wrist joint involves the M. biceps brachii.

Now, the point of all this is: Does this arrangement occur in Archae? Does this arrangement occur in maniraptoran theropods? If so, what possible use could this particular wrist joint be to maniraptoran theropods? Could this be an example of preadaptation (gasp! Sorry to use the "P" word).

Firstly, the wrist joint of Archae does indeed exhibit **some** (but not all) of the features seen in the modern carniate wrist joint. Most notably a lunate carpal, hemispherical in shape, the flat portion of which articulated with the carpometacarpus, leaving the rounded end to articulate with the wrist joint. This provides a flexible wrist joint, although not as flexible as in modern carnates.

Secondly, this configuration is found in several theropod taxa, such as *Deinonychus*, *Velociraptor* and *Stenonychosaurus*. There are two problems here, firstly all these forms postdate Archae, they are all Cretaceous forms; secondly, what would be the use of a nifty flexible wrist to a bunch of theropods which are all teeth and toenails?

OK, problem one is easy to solve. It was a problem that this feature occurred in Cretaceous theropods and in the Late Jurassic Archae only, since to be an important feature and to show a close link between theropods and Archae, theropods coeval with Archae must have had this particular arrangement. Introducing *Coelurus fragilis* a late Jurassic theropod from America. This form does indeed possess the a very similar wrist joint (Ostrom 1980) strengthening not only the theropod-bird link, but also the theropod-Archae-bird link.

The second problem is slightly harder. Why would such a wrist joint be retained in maniraptoran theropods which are dentally and toenail minded when it comes to killing? Ostrom (1995) suggests that the flexibility would come in useful where a grasping action of the hands could augment the killing action of the teeth and/or toenails. I would speculate further. In modern birds the biceps are involved in the folding of the wing. If this were extended to the theropods, the action of pulling the prey into the body would tend to *strengthen* the grip of the theropod by bringing into play the largest muscle on the arm - the biceps, rather than just the wrist muscles. Such a scenario would provide a distinct advantage and thus the retention of the wrist joint in the theropods is not surprising. The title of the sequel to "Jurassic Park" is thus easy: "Jurassic Park II: The cuddle of the Coelusaurs"!

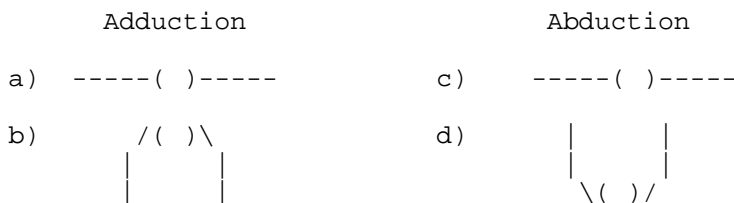
Thus it appears that the flexible wrist joint may have first appeared in theropod dinosaurs as an aid in grasping and retaining prey and was secondarily co-opted by the birds as a mechanism which allowed flight. It may well be that not only were the theropod dinosaurs the ancestors of birds, but that they are the only group which **could** be the ancestor to modern birds.

However, the wrist of Archae does not appear to have the flexibility to allow power flight.

Shoulder Joint

The shoulder joint is also important to modern birds because, not only does it allow full adduction (wing movement down - Fig. 3b), but also full abduction (wing movement up - Fig. 3d)

Fig. 3 (view head on)



i.e. the wing can be drawn up over the back (try it and see how difficult it is). This full range of movement is important in allowing modern birds to power fly. It turns out that the shoulder joint of Archae appears to be intermediate in orientation between some coelurosaurs (theropod dinosaurs e.g. *Deinonychus*) and birds (Jenkins 1993) - just as one would expect from a transitional form. However, whilst the shoulder joint provided a substantial degree of arm (wing) elevation, it is not sufficient to allow full abduction as in modern birds. Thus the shoulder joint of Archae does not appear to allow the full range of movement needed for power flying.

Muscle mass

In modern birds the flight muscles (the pectoralis) comprise up to 35% of the weight of the animal (think of all that juicy meat at the front end of a roast chicken or turkey). It is this massive muscle mass which provides the power needed for flapping powered flight and the ability to take off from a standing start. Ruben (1991) used a pectoralis muscle mass estimate for Archae of approx. 9% of the body weight. This is much lower than in modern birds, but assumed that the muscle attached to the cartilaginous chest wall and not a keel - since a keel is unknown on Archae. The keel is a bony extension of the sternum for the attachment of excess flight muscle in modern birds. If the muscles

did attach to the chest wall in Archae, the length of the pectoralis muscles would have been too short to allow full abduction (see "shoulder joint" above). However, the presence of a small, cartilagenous (and thus not preserved) keel is not out of the question. (Specimens of Archie from the Solnhofen Limestone show no evidence of a sternum. However, recent finds of Archie-like forms from China suggest that Archae did in fact possess a sternum (J.M.V. Rayner, University of Bristol, pers.comm.) Therefore, the 9% figure is a minimum value. This value is well below that for modern birds. Rubin suggested that the maximum power output from the locomotor muscles of extant active reptiles is twice that of birds and mammals, indicating that, if Archae possessed a reptilian physiology, powered flight was a possibility, even with such a small muscle mass. Speakman (1993) questioned this, indicating that the power output of reptiles suggested by Rubin was over-exaggerated, and that Archae would not have had the power output to sustain power flight. Also Speakman pointed out that the theoretical lower limit of pectoralis muscle mass required for take-off from a standing start was approx. 16% of body weight. Thus Archae was not capable of power flight or take-off from a standing start.

The supracoracoideus is an important muscle in modern birds because it is this muscle which elevates or abducts the wing during power flight. Archae did not possess the supracoracoideus arrangement found in modern birds (Ostrom 1974). Thus Archae does not appear to have had the muscle mass nor the muscle arrangement to allow power flight, nor be able to take off from a standing start.

It would appear that the structure and physiology of Archae would mitigate against power flight. But, is this the death knell for Archae's aerobic abilities? Actually, no. Notice the use of the phrase "power flight" in the preceding discussion. Virtually all modern flying birds power are capable of power flight. Power flight is controlled, flapping flight at low speeds and the ability to take off from a standing start. This type of flying requires a large amount of muscle mass and is energetically very expensive. Hence modern birds have a pectoralis muscle mass which comprises approx. 20-35% of body mass. In order to accommodate this extra mass, a keel has developed on the sternum. In other evolutionary developments, flight feathers have become more asymmetric to assist in power flight, and the supracoracoideus muscle system took on the function of assisting in the lifting or abduction of the wing, since this is difficult at low flying speeds.

Power flight is to flying what the 4 minute mile is to running. However, just as being unable to run a 4 minute mile does not necessarily indicate that one is incapable of running, being unable to power fly does not necessarily indicate that Archae was incapable of flying. The characters concerned with flight we see in modern birds are derived, an adaptation to power flight, and thus their absence (or underdevelopment) in Archae cannot be used to suggest an inability to fly.

The structure of the wing of Archae suggests that it was incapable of power, flapping flight at low speeds. However, the amount of adduction and abduction, along with the increased flexibility of the wrist compared with theropod dinosaurs, suggests that some sort of flapping was possible, enough to keep Archae airborne at normal cruising speeds (approx. 7-9 ms⁻¹). Whilst the low pectoralis muscle mass appears to preclude power flight and take off from a standing start, it should be pointed out that some flying birds do possess a muscle mass lower than the 16% by weight lower limit. These include some grebes, who compensate for the lack of muscle mass by having a long running take-off (Speakman 1993). Archae is well equipped with a terrestrial locomotion apparatus. Thus it is possible that Archae could circumvent this problem in the same manner as the grebes.

Flying at normal cruising speeds requires much less energy than power, flapping flight and thus needs less muscle mass to sustain it. As an added bonus, at normal cruising speeds the wing is elevated (abducted) in the upstroke by aerodynamic forces (Rayner 1988) - thus circumventing the need for the supracoracoideus arrangement necessary for power, flapping flight.

Archaeopteryx's Ancestry

Apart from the theropod ancestry, there have been three other suggested ancestral groups for Archae, the Ornithopoda, the Pseudosuchia and the Sphenosuchidae.

The Ornithopod ancestry theory was based on the tibia and pelvis in various dinosaurs which were supposed to approach the condition found in birds. However, most of the taxa used in the original theory in 1883-4 are now known to be saurischian rather than ornithischian. Whilst there was a tendency for the reduction of the hallux (big toe) in some ornithischians, it was never apparently opposable as it is in Archae. It was suggested that Archae had a pelvis which was very ornithischian, however, recent work has shown that this is an artifact of post mortem movement of elements of the pelvic region and there is very little similarity to the ornithischian pelvis. With this, the link between ornithischians and Archae disappears and so it is now thought that there is no link between them.

It was suggested that birds arose from an almost unknown Middle or Late Triassic reptile group, the Sphenosuchidae (Walker 1972, 1974), which also gave rise to the crocodiles. The theory is based on a single specimen of *Sphenosuchus*. However, in their general configurations, neither the skull and jaws, nor the scapulo-coracoid of *Sphenosuchus* is remotely suggestive of affinities with Archae (Ostrom 1976). More recently, the main proponent of the crocodile-bird hypothesis has stated that the hypothesis "has become so tenuous that it is very difficult to sustain." (Walker 1985, p. 133)

The pseudosuchian link was very much favoured earlier this century. However this was, by and large, based on Heilmann's reconstruction of the Berlin specimen, which has since proven to be inaccurate. According to Ostrom (1976 p. 159):

"There are very few anatomical resemblances between *Archaeopteryx* and any pseudosuchian. In fact, only in *one* feature does *any* pseudosuchian resemble *Archaeopteryx* more closely than does any theropod, this being the tibia to femur ratio in *Scleromochlus*, *Lagosuchus* and *Lagerpeton*, where the tibia is from 20% to 30% longer than the femur. Amongst theropods, only in struthiomimids, *Compsognathus*, *Microvenator* and *Deinonychus* is the tibia longer than the femur but by only 10% to 15%. In *all other features*, the closest resemblance to the morphology preserved in *Archaeopteryx* is found in coelurosaurian theropods." [original emphasis]

Chiappe (1995) provides a very good review of the early evolution of birds.

Protoavis

Some people like to claim that the finding of a fossil bird from the Triassic of Texas (*Protoavis*) proves that Archae cannot be transitional between dinosaurs and birds because *Protoavis* predates Archae by 75 million years. This is, of course, errant nonsense, mainly because no one is claiming that Archae is *the* transitional species between dinosaurs and birds, merely that Archae represents a grade of organisation which the proposed lineage went through to get from dinosaurs to birds. Archae is, I'm sorry to say, out on a limb, evolutionarily speaking. It represents a side branch, useful for comparative purposes, but not in the thick of things. So even if there were birds in the Triassic, that fact would not diminish Archae's importance as an indicator that "yes, birds could have evolved from dinosaurs."

However, notice the "if" in the previous sentence. There are major problems with *Protoavis*. On the Chatterjee (1991) interpretation, Ostrom (1991) has this to say [my paraphrase]: The only published material from the fossil is a monograph in the Philosophical Transactions of the Royal Society of London. However, this only describes the head. This is badly crushed and all the pieces have been extracted from the matrix, rendering precise placement of the pieces open to question. The description is done from an avian viewpoint, with no counterview (e.g. is this a dinosaur?) used. The skull is so badly crushed that diagnostic features are not preserved. Therefore the published material does not support the view that this is a bird. Indeed a viewing of the fossil by Ostrom (in admittedly less than ideal surroundings) showed that the diagnostic features which could identify the fossil either way are badly crushed and it is doubtful whether any definitive statement could be supported by the fossil. It may be a bird, it may not.

Please note that this questioning of *Protoavis* as a bird is no "it can't be a bird because it predates Archae" evolutionist backlash. As has been pointed out, even if it is a bird, it does not detract from the evolutionary importance of Archae.

Conclusions

Archaeopteryx is a bird because it had feathers. However, it retained many dinosaurian characters which are not found in modern birds, whilst having certain characters found in birds but not in dinosaurs. By virtue of this fact *Archaeopteryx* represents an example of a group in transition - a representative which, although on the sidelines in the dinosaur to bird transition, an echo of the actual event, still allows a brief glimpse into the possible mechanism which brought about the evolution of the birds and by its very existence shows that such a transition is possible.

Acknowledgements

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This is a University of Ediacara Palaeontological Contribution.

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On *Archaeopteryx*, Astronomers, and Forgery

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Introduction

Archaeopteryx *lithographica* is regarded as one of the most important fossils ever discovered. This isn't because of any uniquely transitional nature, since many transitional forms exist (e.g. the synapsid to mammal transition), but due to the fact that *Archaeopteryx* is such a good example of evolution. The skeleton is essentially reptilian, with close affinities to theropod dinosaurs, and possesses teeth, a long bony tail, abdominal ribs and three digits on each hand - characters absent in birds. However, the specimens also show certain bird characters such as a furcula (wishbone) and a retroverted pubis (characters also shared with some dinosaurs) and a opposable hallux (big toe) for perching. Along with these other avian characters, the most spectacular feature is the distinct impression of feathers around the forelimbs and tail, feathers almost exactly like those of modern birds.

The authenticity of *Archaeopteryx*, or more specifically the authenticity of the feather impressions, was questioned in 1985 by a group which included, Prof. F. Hoyle (astronomer), Dr. N. Wickramasinghe (mathematician), Dr. L. Spetner (physicist), Dr. R. Watkins (medical doctor) and J. Watkins (photographer) in a series of articles published in the British Journal of Photography (Hoyle *et al.* 1985; Watkins *et al.* 1985a, 1985b, 1985c). Interestingly, one of the authors (Dr. Spetner) was claiming that *Archaeopteryx* was a fake as early as 1980 (Trop 1983). Apparently on the sole fact that the London specimen was sold by Dr.C Haberlein and the Berlin specimen was sold by Dr Haberlein's *son!* (The Harberleins were well known collectors, possessing one of the finest collections of Solnhofen fossils).

Needless to say, these claims were vigorously opposed by the British Museum of Natural History (BMNH). Several people within the Museum collaborated to refute the claims of forgery. These were A. Charig (chief curator of fossil amphibians, reptiles and birds, BMNH), A. Milner (principle scientific officer - fossil amphibians, reptiles and birds, BMNH), C. Walker (senior scientific officer, fossil amphibians, reptiles and birds, BMNH), F. Greenaway (principle photographer, BMNH) and P. Whybrow (photographer, BMNH).

Watkins *et al.* Opening Statements

In the first part of their claim that the feather impressions were a forgery, Watkins *et al.* stated that,

"Although several other reptilian fossils have subsequently been reclassified as *Archaeopteryx*, the first two referred to above [the London and Berlin specimens - cn] remain unique in that they are clearly of the same prototype and possess unmistakable feather imprints." (Watkins *et al.* 1985a, p. 264-265).

This was reiterated by Hoyle *et al.* (1985, p. 694), who suggested that

"the only undeniable featherlike impressions are therefore those on the single feather of 1860, on the British Museum specimen of 1961 and the Berlin specimen of 1877".

This is incorrect. It is true that none of the other specimens have feather impressions as good as those found on the London and Berlin specimens and that the recognition of feathers on the Haarlem specimen would not be possible without reference to the London and Berlin specimens. However, the Eichstatt specimen has clear feather impressions (Wellnhofer 1974) and the Maxberg specimen has impressions in which the structure of the feather is discernable as being typical of that in modern birds (de Beer 1954; von Heller 1959; Charig *et al.* 1986). Not only that, the feathers of the Maxberg specimen clearly refute any possibility of forgery because they continue *under* the bones of the skeleton and are overlain by dendrites (von Heller 1959; Charig *et al.* 1986). (Dendrites are crystal aggregates occurring along flat surfaces, with a tree-like branching pattern. They often occur in cracks or along bedding planes). The Haarlem specimen does show faint feather traces (Ostrom 1972). Feather traces have also been described from the Solnhofen specimen (Wellnhofer 1988). The most recent find, the Solnhofen-Aktien-Verein specimen, has also been described as possessing feather traces (Wellnhofer 1993).

Another statement is,

"The significance of *Archaeopteryx* lies in the fact that it represents the only unquestionable case of a fossil showing a transition between two vertebrate classes, aves (birds) and reptilia (reptiles)." (Watkins *et al.* 1985a, p. 256).

Again, this is incorrect. There are numerous examples in the fossil record, with probably the best documented example being the transition between the synapsid reptiles and the mammals (e.g. Kemp 1982; Benton 1990; Colbert & Marales 1991).

A third statement concerns the photography itself. In 1984, Watkins *et al.* took comprehensive photographs of the London specimen, held at the BMNH, on colour transparency film with a hand-held 35 mm SLR camera and low angle tangential flash lighting. The resulting slides were then enlarged by projecting the slide onto a distant screen and by making black and white prints (Watkins *et al.* 1985a). When describing the technique used by Watkins *et al.*, they comment,

"Such [photographic] studies have been made earlier but these have inevitably been limited by the techniques available in the past." (Watkins *et al.* 1985a, p. 265).

This is also incorrect. As the response from the Museum indicates,

"As professional photographers we have studied the fossil under various combinations of light sources, emulsions, ultraviolet reflectance and fluorescence, filtered UV fluorescence, intensive scanning by infrared TV and high photomicrography. These studies have taken place over a number of years." (Parmeter & Greenaway 1985, p. 458).

Indeed, far from being in any way superior to other methods,

"the cursory examination and poor photographs of the authors of the articles [Watkins *et al.* - cn] bear no comparison with the close scrutiny and exacting standards of the Museum." (Parmeter & Greenaway 1985, p. 458).

The photographs themselves have too much contrast and too soft a focus (Charig *et al.* 1986), making detailed study difficult and these

"newer photographs compare extremely unfavourably with photographs of the same specimen taken by museum photographers who, several decades ago, were already using low-angle oblique lighting with far greater success" (Charig *et al.* 1986, p. 623) (See de Beer 1954 for an example of this.).

Indeed, Watkins *et al.*

"readily concede the rudimentary nature of their photography, but were looking in the time available for evidence to prove or disprove certain specific theories. Ideally they might first have inspected the

Museum's photographic records, but, as ever, those holding controversial views preferred to look for themselves before disclosing them" (Crawly 1985, p. 458).

In yet another statement, the authors state,

"It is now generally believed that the skeleton is largely reptilian except for the furcula (wishbone) which is bird-like" (Watkins *et al.* 1985a, p. 256).

This is misleading. The opposable hallux is also an avian feature as is the position of the pelvis (although this also occurs in some dinosaurs) (see for instance, Ostrom 1976).

The Main Claims and Evidence, For and Against

Using a series of photographs, Watkins *et al.* claimed that the feather impressions were fakes. The method used to create the forgery was via the pressing of chicken feathers into a thin layer of artificial cement surrounding a small reptile skeleton. (It should be noted here that although one of the authors - Dr. Spetner - claimed that chicken feathers were used, the impressions do not correspond to chicken feathers, but are more like rail feathers). The cement would have been made by mixing limestone from the same deposit with some binder and which was spread thinly over the surface of the slabs. As corroborating evidence of this several observations were cited:

i) The difference between the surface textures of the limestone in the feathered and unfeathered areas was cited as evidence of the presence of a cement layer around the feathers (Watkins *et al.* 1985a).

The difference in surface texture is certainly real. However Charig *et al.* (1986) explain it as being due to the impression of the animals body on parts of the surface. An analogy used was likening it to the differences in texture seen between a human footprint in mud and the surrounding mud.

"In other words, it was the feather impressions that caused the differences in surface texture; not that a difference in surface texture (due to some other cause) permitted the preservation of the impressions in some places and prevented it in others" (Charig *et al.* 1986, p. 623).

If a layer of cement is present, then some sort of discontinuity should be visible between the true limestone and the cement, on the surface and/or in vertical section (a vertical section is a section cut through the slab, at 90 degrees to the fossil). No such discontinuity has been found, even in vertical section. There does appear to be a division in vertical section whereby an upper 500-850 micrometre (1 micrometre = 1/1000 millimetre) layer is separated from the lower layer by a dark band. However, the upper layer shows the same granular structure as the lower layer and the structure is continuous through gaps in the dark band (Charig *et al.* 1986). Also the complete lack of air bubbles and the presence of calcite crystals indicate that the whole section is original. Besides, the upper layer is far too thin to receive any feather impressions (Charig *et al.* 1986). A further point worth raising here is that any organic bonding material available to a forger in the 19th century for mixing cement would have shown some evidence of cracking or shrinking away. No such cracking or shrinkage has been observed.

ii) The presence of detailed feather impressions on the main slab, coupled with their absence on the general surface of the counterslab was taken as evidence that the cement layer on the counterslab was removed either because it was too difficult to match the feather impressions or that material fell off when the counterslab was hammered (Hoyle *et al.* 1985; Watkins *et al.* 1985b).

Fossils from the Solnhofen Limestone are commonly found concentrated on one part of the slab, with only a faint impression on the counterpart. This is because the part containing the bulk of the fossil represents the covering sediment, into which the body of the animal protruded. The faint impression on the counterpart represents the impression made on the lagoon bed where the animal came to rest on the bottom (e.g. Swinburne 1988). In other words, the bulk of the specimen lay projecting above the sea floor and was eventually encapsulated within the overlying bed. Upon splitting along the original sea floor surface, the bulk of the fossil will be preserved in the bed above the split, while the original bedding surface will retain only an impression. Thus the part containing the bulk of the fossil represents the overlying bed. This difference between a well preserved part and a poorly preserved counterpart is well known in Solnhofen fossils. Thus, using this differential preservation as a criterion for forgery means that all Solnhofen fossils must be suspect!

iii) The occurrence on the slabs of smooth, flattened, slightly elevated areas resembling "blobs of chewing gum" (Watkins *et al.* 1985a, p. 265), only a few millimetres in length and not always matched by corresponding depressions on the opposite slab (Watkins *et al.* 1985b), some bearing faint but detailed feather impressions. This was claimed to be fragments of the lost cement layer which was not fully removed (Watkins *et al.* 1985b). Hoyle *et*

al. (1985, p. 694) stated that these "blobs" are

"without any place to go should the main slab and counterslab be closed like the leaves of a book."

In other words they claimed that the slab would not fit tightly with the counterslab since the "blobs" did not correspond to any depression in the counterslab.

These "blobs of chewing gum" appear to be natural irregularities in the surface of the slab. Indeed,

"careful casting of the surfaces of both main slab and counterslab shows that there is always a good fit between the two, except where it has been destroyed by subsequent preparation. In no case is there an elevation on one slab 'without any place to go should the main slab and counterslab be closed like the leaves of a book.'" (Charig *et al.* 1986, p. 623).

iv) The regularity of the side veins of the feather impressions was claimed to indicate a forgery, since the limestone could not have split so evenly as to break along the length of the feathers (Watkins *et al.* 1985b).

The Solnhofen Limestone is well known for its smooth, level bedding planes along which it readily splits, providing an ideal, flat, smooth surface for use in printing and for exposing fossils. The extremely fine texture, essential for printing, is ideal in preserving the most delicate anatomical structures, such as the medusae of jellyfish, the hairlike setae of crustaceans and the wing membranes of pterosaurs (Charig *et al.* 1986; Barthel *et al.* 1990).

v) The apparent "double strike phenomenon" was claimed to indicate that the same feather was printed twice in a slightly displaced position and was thus indicative of a forgery (Watkins *et al.* 1985a).

The reproduction of a double impression would be harder to forge than a simple single impression, thus making it unlikely that a forger would attempt such a double impression. Besides, it is also observed on the Berlin specimen and has recently been much more convincingly explained as representing two overlapping feathers (Rietschel 1985).

vi) The tail is in fact one large tail feather and the caudal vertebrae are in fact the central axis of the feather (Watkins 1985a).

Not only is the tail "obviously segmented" (Charig *et al.* 1986, p. 625), individual feathers can be seen attached to the vertebrae via ligaments (de Beer 1954; Charig *et al.* 1986).

Apart from the above comments, Charig *et al.* (1986, p. 623-624) cite further evidence against a possible forgery.

"Our conclusive evidence of the authenticity of the *Archaeopteryx* holotype, however, is provided by what appear to be a number of fine lines on the main slab that run in various directions across the feather impressions in the region of the forelimb; some of them extend through the bony elements of the skeleton and on to the tail. They are difficult to spot with the naked eye, but their presence is shown with great clarity by critically lit ultraviolet photography. Associated in a few places with the more easily visible linear staining of an orange-brown colour, they are presumably hairline cracks and are generally filled with mineral matter. These cracks are also present on the counterslab in precisely the same positions."

This indicates that there is no intervening cement layer between the two slabs, as does the presence of manganese dioxide dendrites which have grown over the feather impression in some areas. These too match precisely on the two slabs, even in microscopic detail (Charig *et al.* 1986).

Why?

Watkins *et al.* offered two reasons for the forgery, both implicating the then Superintendent of the Natural History departments of the British Museum, Richard Owen (Runyard 1985). Firstly they suggested that Owen forged the impressions to provide evidence in support of Darwin's ideas on evolution. Given Owen's hostility towards Darwin and his ideas (not towards evolution, merely towards Darwin's ideas on evolution) this is extremely unlikely. The other reason was that Owen laid a trap for Darwin, to tempt Darwin into making a fool of himself by declaring the fossil proof of evolution and then revealing the "evidence" to be a forgery. This however is ludicrous. Owen himself made a detailed description of the specimen (Owen 1863) thus laying himself and his reputation open to ridicule should the specimen prove to be a forgery. Besides, although Darwin knew of the specimen, he made only passing reference to it, describing it as "that strange bird *Archaeopteryx*" (Darwin 1866). He knew that one specimen could not prove his ideas on evolution.

The Saga Continues

In 1988 Spetner, Hoyle, Wickramasinghe and Magarits published a further piece concerning the analysis of two small rock samples taken from the London specimen, one from the feather region (called FM) and one from one side of the slab, away from the fossil (called MM). After the analyses were complete, several claims were made.

"Our contention is that the feather impressions were forged onto a fossil of a flying reptile." (Spetner *et al.* 1988, p. 15).

The only flying reptiles known (excluding *Archaeopteryx* and related forms) are the pterosaurs. However, *Archaeopteryx* does not possess the skeletal morphology to enable it to fly in the same way that pterosaurs did. Pterosaurs have been found in the Solnhofen limestone, complete with impressions of the wing membranes. No fossil reptile with a skeletal morphology similar to *Archaeopteryx* has been found with these membranes. Spetner *et al.* give no comment as to how this "flying reptile" managed to fly without the aid of feathers or, apparently, a membrane similar to pterosaurs. Indeed, it is likely that such a reptile could only have flown if it possessed feathers.

"The hairline cracks that they report to appear across the feathered region could have occurred naturally on the forgery premise. As the stone underwent slight movement, a crack in the underlying stone would tend to come through a thin layer of cement that had been placed on the surface." (Spetner *et al.* 1988, p. 16).

This fails to explain what is observed. The "crack" had been naturally infilled with calcite prior to the alleged forgery, thus the crack as a space to initiate upward propagation, no longer existed (fig 1).

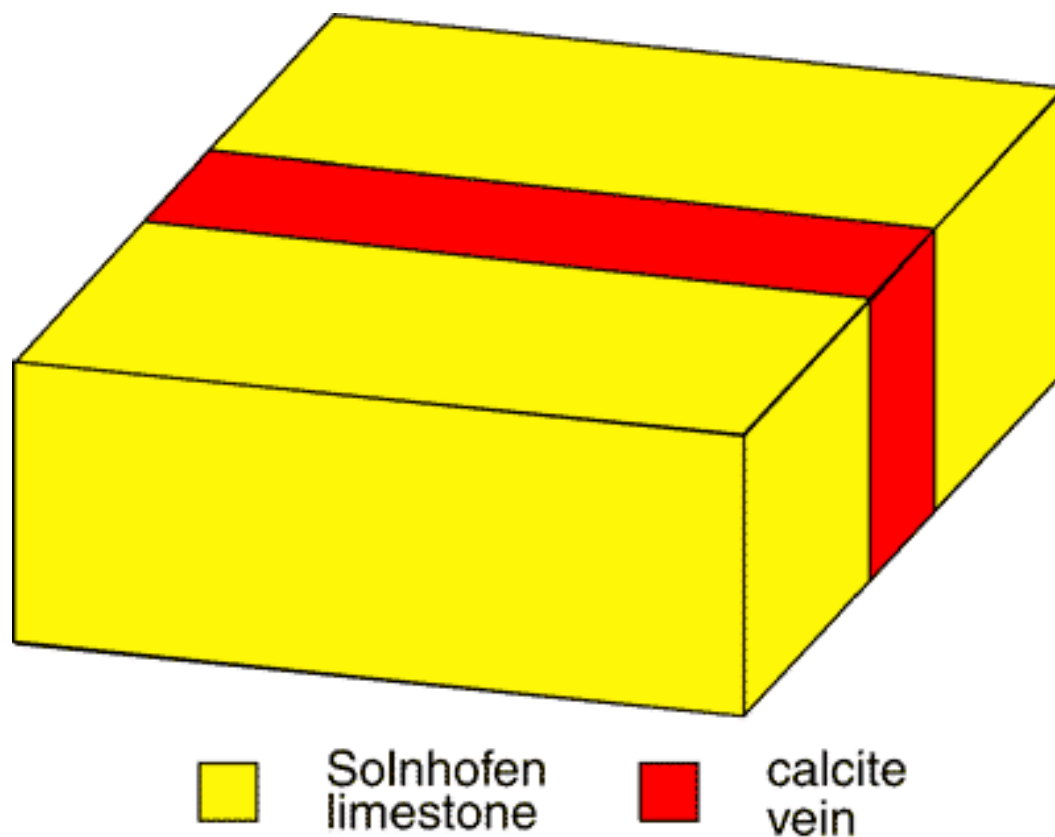
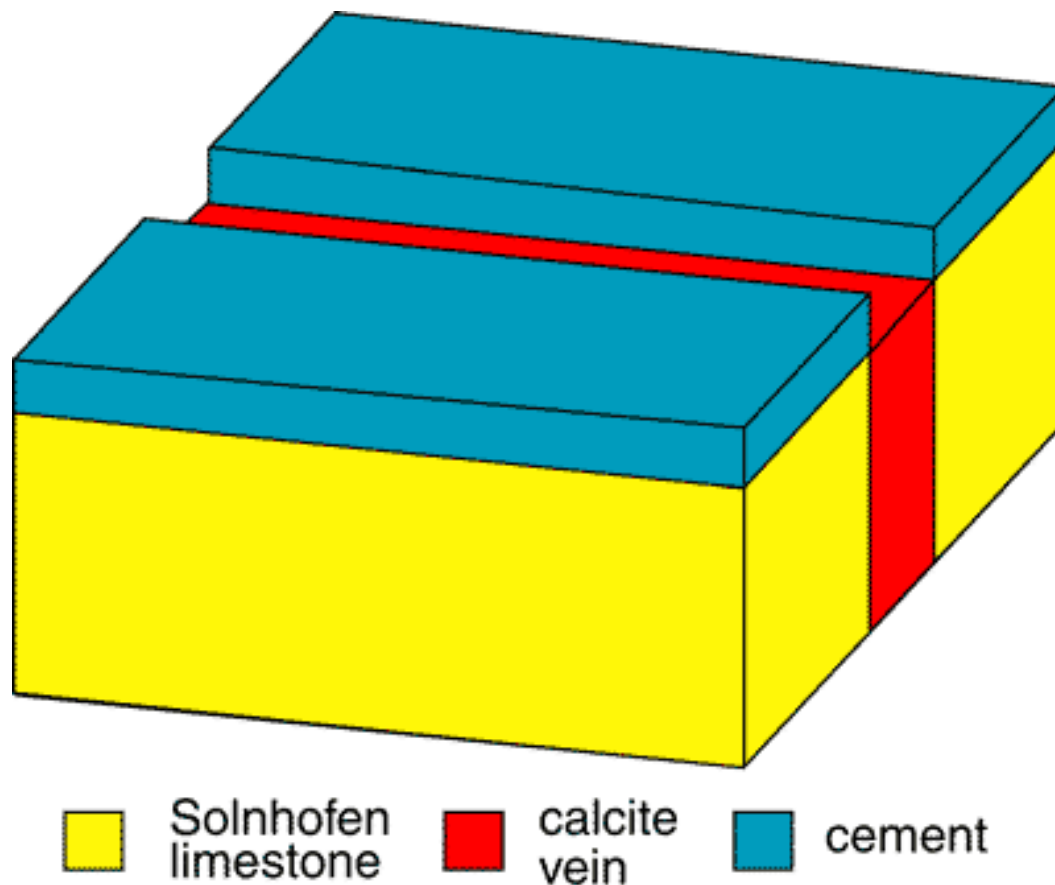


Figure 1.

Not only that but if the crack did propagate upwards, there would be a gap - within the crack - between the top of the calcite infilling the original crack and the top of the added layer of cement (fig 2).



Solnhofen limestone
 calcite vein
 cement

Figure 2.

However, analysis of the slab shows the situation to be like that in Fig 1. So, in order for Spetner *et al.* to be correct, not only does the crack have to propagate upwards, but the infill has to mobilize and fill the gap between the old top of the slab and the top of the cement layer. This cannot happen merely by a "slight movement" of the slab. The presence of a number of these cracks in the configuration shown in Fig. 1, refutes the presence of a cement layer. The explanation in Spetner *et al.* (1988) is not viable.

"With regard to the claim that the dendritic pattern appears on the feathered region, we can only say that they must have been mistaken. Fig. 1 shows the same dendritic pattern to which they referred, but it shows it in much greater detail than their figure. Fig. 1a is a photograph of the same area as shown by Charig *et al.* Fig 1b is a map of the area shown in Fig 1a to enable the reader to locate the detail in the photograph, the viewing of which may be facilitated by the use of a magnifying glass. In Fig 1, the dendritic pattern can be seen to lie wholly *off* the wing region, only abutting it on the pattern's lower edge. The outline of the wing is indicated in Fig 1b by a heavy double line. Note that the dendritic pattern lies totally above the wing and just abuts it on the lower edge. . . . The museum refuses us any additional access to the fossil so we have to make do with photographs that we already had. In any case, what is clear is that the dendritic patterns do not lie *on* the feathers as claimed by Charig *et al.*" (Spetner *et al.* 1988, p. 16, original emphasis).

The claim that the dendritic pattern does not lie on the feathers is false. Fig 3b from Charig *et al.* (1986) clearly shows the dendritic pattern overlapping the feather impressions (note: this is clearest on the *counterpart* slab, fig 3b, not the slab figured by Spetner *et al.* - possibly because they did not photograph the counterpart slab?). Also Spetner *et al.*'s claim relied on their poor quality photographs of one area and a rather crudely drawn "map". Charig *et al.* (1986, p. 624) clearly stated that the dendrites "have grown over the feathers in *places*" (emphasis added). There is more than one occurrence. This, combined with the higher quality published photographs in Charig *et al.* (1986, fig. 3) clearly showing the dendrites overlapping the feathers, means that this refutation by Spetner *et al.* is unconvincing.

"Figs 4 are SEM photographs of the samples. A typical photograph of the MM shown in Fig 4a, which shows calcite grains varying in size from about 1 to 5 micrometres. These grains are typical of the fine carbonate structure one would expect to find in Solnhofen limestone. The FM, on the other hand can be seen to consist of a similar material with the addition of an unknown non-crystalline substance." (Spetner *et al.* 1988, p. 16-17)

It should be pointed out that their fig. 4 comprises 6 SEM photographs, one of the matrix material and 5 of the

feather material. It is difficult to accurately compare the two samples since the SEM of the matrix material is shown at a higher magnification than those of the feather area (with the possible exception of Figs. 4c and 4f which show close-ups of the "anomalous material", but these two have no scales included). Thus any apparent visual difference in the bulk make-up of the two samples (excluding the "anomalous substance") is an artifact of differential resolution. There appears to be no evidence of a fine binder of any kind in the rock matrix of the FM (feather) sample. In fact the matrix looks identical to the MM (matrix) sample.

"The unknown substance comes in various shapes. In some cases it has a rod-like appearance to which carbonate grains have adhered, as seen in Figs 4b and 4c. In other cases this substance has an odd shape as shown in varying magnifications in Figs 4d, 4e and 4f." (Spetner *et al.* 1988, p. 17)

The "rod-like" form is long and thin and hair-like. The "odd shape" is an amorphous, round blob, 0.0025 mm in diameter. The carbonate grains adhering to the unknown substance are extremely small, at 0.0006 mm.

"Note that the carbonate grains lie *both above and below* the non-crystalline substance. If the material were simply applied to the surface of the fossil as a preservative, as the museum proposes, one would expect to find it lying *wholly above* the carbonate grains." (Spetner *et al.* 1988, p. 17, original emphasis).

This claim is not supported by the photomicrographs. These show that the unknown material is clearly separate from the matrix carbonate. They appear to lie wholly above the carbonate grain matrix. Spetner *et al.* suggest that because the material is not *at* the surface, it cannot have been recently introduced except as part of a cement. However, the unknown material is clearly not forming part of any cement. Also the size of the sample (a few micrograms) means that the surface under examination is only a few 10ths of a millimetre below the original surface - although it is difficult to judge where the original surface was, since there is no indication of orientation in the photomicrographs - thus introduction into minute cavities in the surface cannot be ruled out. The carbonate grains which are coating the unknown substance are very small and were most probably dislodged during the cleaning and/or casting process, and adhered to the unknown material in the same manner that dust adheres to surfaces.

"An X-ray chemical analysis of the unknown substance in Fig. 4f is shown in Fig. 5. At low irradiation energy (10 kV) the analyser shows peaks of calcium, silicon, sulphur and chlorine. At higher irradiation energy (25 kV) peaks of zinc and lead appear. The intensity of the X-rays emitted from the elements detected in the unknown substance in the FM sample was relatively low. This low intensity suggests that the main chemical component of the unknown substance has an atomic number too low to appear in the analyses. Since our instrument does not detect elements whose atomic numbers are lower than that of sodium. We can only suspect that the unknown substance is principally carbon, and that it is likely to be of organic origin. The size of the sample that we received from the Museum did not permit a true chemical analysis in which organic substances could be identified." (Spetner *et al.* 1988, p. 17).

Their Fig. 5 is labeled, "X-ray luminescence results from amorphous body shown in Fig. 4f." However this is incorrect. The analysis was obtained using Energy Dispersive Spectrometry - "X-ray luminescence" is not a term that is used to describe X-ray analyses. The analysis produced peaks for calcium, as expected, but also for silicon, sulphur and chlorine (see Fig. 3) - not elements usually associated with organic matter.

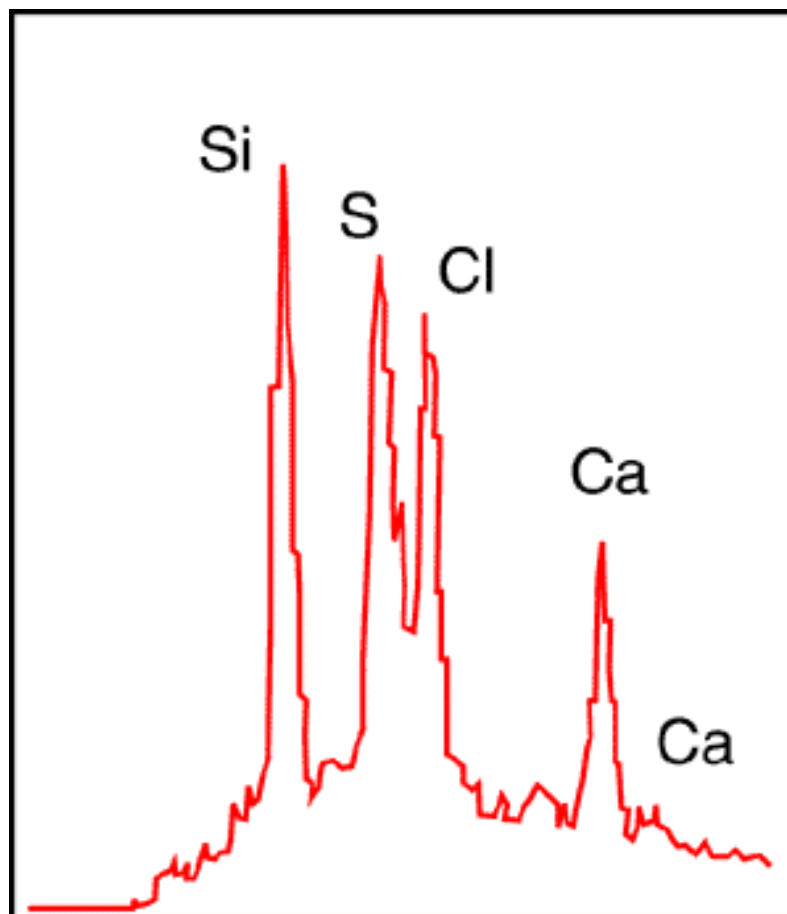


Figure 3.

The sulphur peak must be regarded as suspect since the low resolution (140-150 eV) of energy dispersive spectrometry will fail to differentiate between a K α sulphur peak and a K α lead peak, especially at 10 kV. At 25 kV a lead peak appears, indicating the presence of lead and thus at least a portion of the "sulphur" peak, at 10 kV, must be regarded as lead (again a substance not associated with organic matter).

Several things should be pointed out at this point:

- Some time prior to the removal of samples from the *Archaeopteryx* specimen, the specimen was thoroughly cleaned to remove accumulated grime and old preservatives.
- This process was highly successful, but not 100% successful.
- This process was not carried out under 'clean' or dust-free conditions.
- This process also required some vigorous brushing of the specimen away from the actual bones (especially the wing area).
- Once cleaned, a master silicone rubber mould was taken.

When these facts are taken into consideration, a much more likely explanation presents itself.

The "unknown substance" analysed by Spetner *et al.* was, most probably a fragment of silicone rubber which had become entrained just below the surface of the slab during its fluid phase. But would a piece of silicone rubber produce the X-ray spectrograph shown? Well, the chemical formula of silicon rubber is shown in Fig. 4.

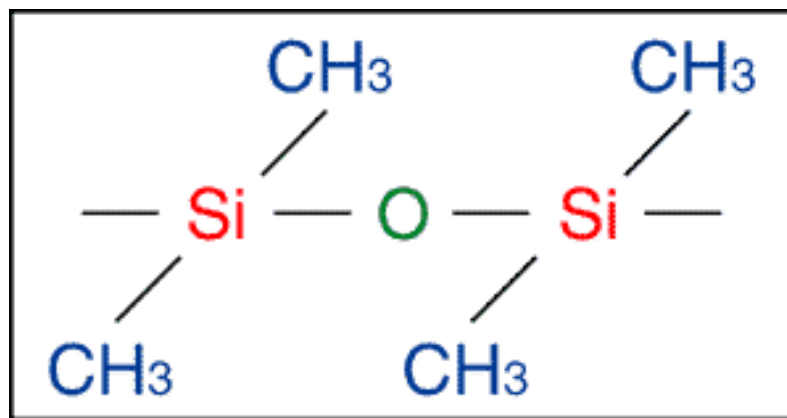


Figure 4.

The large amount of silicon found in silicone rubber can explain the silicon peak seen in the spectrograph. As for the claim that the low intensity of X-rays emitted

"suggests that the main chemical component of the unknown substance has an atomic number too low to appear in the analyses. Since our instrument does not detect elements whose atomic numbers are lower than that of sodium. We can only suspect that the unknown substance is principally carbon, and that it is likely to be of organic origin." (Spetner *et al.* 1988, p. 17)

The presence of carbon, hydrogen and oxygen in silicone rubber (see Fig. 4), all with atomic numbers below that of sodium, can account for this, without the need to invoke organic matter.

But what of the chlorine peak? Well, the presence of chlorine is a problem if the material was of organic origin, but is no problem if the material is silicone rubber. Silicone rubber is commonly fixed with substances called Trichlorosilanes (SiCl_3H) [no prizes for guessing what the "-chloro-" stands for! :-)], the mixing of which results in the locking together of long polymers strands of the rubber (Fig. 5).

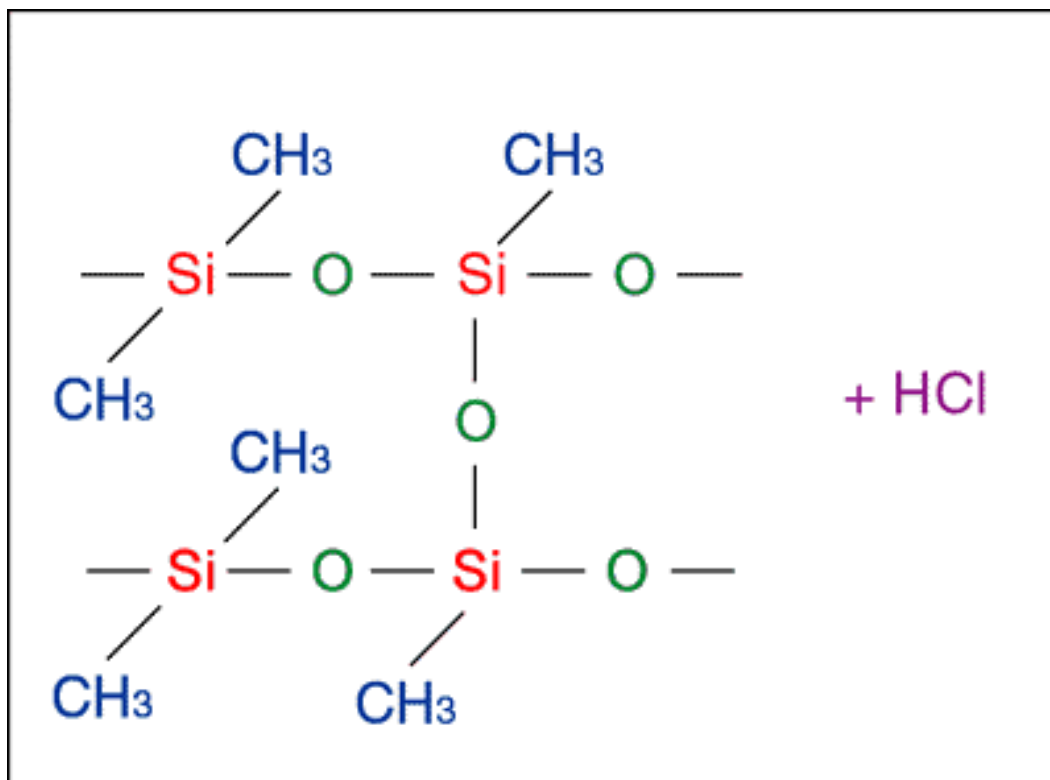


Figure 5.

A byproduct of this reaction is HCl. Thus the chlorine peak could represent unreacted Trichlorosilane fixer, or a residue of HCl.

No evidence for the presence of an organically bound cement is presented. Photomicrographs indicate that there is no difference in the matrix from the fossil area as compared with the limestone. No organic matter was detected in the samples analysed. The presence of organic carbon is a suggestion presented by Spetner *et al.*, but is one which is inconsistent with the chemical analyses presented in the article. These analyses suggest that anomalous material analysed by Spetner *et al.* is more likely to be silicone rubber from a mould prepared before the rock sample was

taken, than an organic residue from - or included in - some sort of cement.

Hoyle and Wickramasinghe appear to still be confused over the preservational style of *Archaeopteryx*.

"The original piece of rock containing the genuine *Compsognathus* fossil was probably split with a bias of bones towards the main slab, but the bias could not have been so well marked as we see . . ." (Hoyle & Wickramasinghe 1986, p. 51).

As Swinburne (1988) points out, the splitting is a fundamental property of the rock (it splits along a bedding plane, leaving the fossil mostly on one side. Also,

"it would be impossible we think for a bird-like creature to fossilise in such a way that the impressions of tens of thousands of feather barbs were all confined in an ordered way to a single surface, even if it be supposed possible to find that initially unknown unique surface working inwards from a boundary of a chunk of rock" (Hoyle & Wickramasinghe 1986, p. 59).

As explained by Swinburne,

"Hoyle and colleagues have misapplied the depositional theory, unaware of the attitude of the fossil. *Archaeopteryx* came to lie belly-up with wings outstretched on an extremely flat, well consolidated surface. It was covered by a pulse of suspended sediment which rained down into the stagnant pond in which it lay. The wings were then flattened against this plane by the weight of overlying sediment." (Swinburne 1988, p. 276).

This surface would eventually be the one which splits resulting in the assymmetric preservation of the part and counterpart.

Conclusions

The evidence claimed by Watkins *et al.* to indicate that the feather impressions are a forgery appear to be easily explainable by natural processes. Detailed study of the London specimen both across the surface and in vertical section have failed to provide any evidence to support the contention that a layer of cement is present. The method claimed to have been used to produce the forgery cannot explain the presence of fine lines crisscrossing the fossil, or the matching dendrites on the slab and counterslab, which occur on top of the feather imprints. The feather imprints on the Maxberg specimen, despite claims to the contrary, are clearly identifiable as such. In this case, forgery of the type envisaged by Watkins *et al.* can be discounted because of the fact that the impressions run underneath the bony elements of the skeleton.

Something that should be obvious to anyone is that

"any conclusions about the authenticity of the fossil should be based on the best possible evidence. Photographs are just one ingredient of such evidence" (Parmeter & Greenaway 1985, p. 458).

Watkins *et al.*, however, cite as evidence of their claims a set of "rudimentary," "poor" photographs having "too much contrast and too soft a focus," without looking at the much more extensive and better quality Museum photographs.

The claims that the feathers of *Archaeopteryx* are fake has been shown to be unsupported. Thus the claim that "the significance of *Archaeopteryx* lies in the fact that it represents the only unquestionable case of a fossil showing a transition between two vertebrate classes, aves (birds) and reptilia (reptiles)" has been upheld. In other words, Watkins *et al.* claim that *Archaeopteryx* represents a transitional form, but cannot be accepted as such because it is a forgery. Since the claim of forgery has not been substantiated, *Archaeopteryx* must therefore be an example of a transitional form by Watkins, *et al.*'s own admission (notwithstanding the fact that they mischaracterise *Archaeopteryx* as the "only" case).

I doubt however, that this particular quote will show up in any creationist literature.

Acknowledgements

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This is a University of Ediacara Palaeontological Contribution.

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Archaeopteryx:
Answering the Challenge of the Fossil Record
[Chris Nedin](#)
[Last Update: October 8, 1996]

This is dedicated to the memory of [Tero Sand](#) (1965 - 1996).

Most literalist creationists argue that there are no transitional forms (e.g. Morris 1967, Gish 1979, 1985, 1995). Cracraft (1983) suggests that this argument,

could well be the paradigm example characterizing the entire creation-evolution controversy for it illustrates how creationists have taken an extremely complex scientific question, simplified the matter to the point of misrepresentation, and then have promoted the blatantly false claim that the fossil record supports the creationist world view. Indeed, from the manner in which creationists have discussed this issue, one can only conclude that either the creationists have consciously adopted the tactic of outright distortion or they are so abysmally ignorant of the scientific arguments and data that their apparent distortions are only accidental, not purposeful. (p. 178)

Cracraft also discusses the methodology employed by creationists on this topic.

Creationists have adopted three lines of argumentation against the existence of transitional forms: (1) they quote liberally from various paleontologists as to the paucity of transitional forms; (2) they define the concept of "transitional form" in a way that is distinctly different from the evolutionists' use of the term; and (3) they simply deny the existence of intermediate taxa, whilst ignoring the vast scientific literature opposing their position. (p. 179).

In discussions about the existence of transitional forms in the fossil record, no fossil has caused more feathers to fly than *Archaeopteryx*, due to its pride of place as a classic example of a transitional form - in evolutionary terms, a form which exhibits characters shared with one group and only that group, whilst also exhibiting other characters shared with another group and only with that group (e.g. Kitcher 1982), in other words a morphological intermediate. Dr. Duane Gish of the [Institute for Creation Research](#), is probably one of those most vocal in crying foul at the recognition of *Archaeopteryx* as a transitional form (e.g. Gish 1979, 1985, 1995). There have been various commentaries on passages from Dr. Gish's 1978 book *Evolution? The Fossils Say No!* (e.g. Kitcher 1982; Cracraft 1983; Raup 1983; Halstead 1984; Strahler 1987; Blackburn 1995), but relatively little commentary about Dr. Gish's 1985 book *Evolution: The Challenge of the Fossil Record*. This article looks at a small portion of the 1985 book - that pertaining to *Archaeopteryx* - in light of Cracraft's comments.

Dr. Gish has recently (1995) published an updated version of his 1985 book, called, [Evolution: The fossils still say NO!](#). An analysis of the treatment of *Archaeopteryx* in that book is underway. However, the well known half life of literalist creationist material, long after it has been superceded, means that this may still represent a valuable resource for people replying to literalist creationist statements about *Archaeopteryx*.

Some material from *Evolution: Challenge of the Fossil Record* has been rendered obsolete by new data accrued in the 10 years since the book was first published. However...

"In reference to *Archaeopteryx*, *Ichthyornis*, and *Hesperornis*, Beddard stated: "So emphatically were all these creatures birds that the actual origin of Aves is barely hinted at in the structure of these remarkable remains" (Beddard 1898, p. 160)." (p. 110)

Despite the fact that Beddard was writing in 1898, when only two specimens of *Archaeopteryx* were known, Beddard's (1898, p. 6) criterion for identifying birds is instructive. "A bird may be known by its feathers; to define a

bird it is only necessary to refer to its covering of feathers. No other animal has any structures comparable to a well developed feather." Note however that Beddard was in no doubt of the uniqueness of *Archaeopteryx*, listing some 8 characters in which "...*Archaeopteryx* differed from all known birds." (p. 532). It is interesting to note here that the recent discovery of *Sinosauropteryx* - a dinosaur in China which appears to preserve feathers - suggests that, at least as far as fossil species are concerned, feathers may not be such a good defining character for birds

These characters are shared with reptiles and have become more refined with the finding of additional specimens, especially the Eichstädt specimen, described in 1974. Such were the differences between *Archaeopteryx* and all other birds that Beddard (1898, p. 159) was prompted to write, "[t]here can be no question, in my opinion, that birds must be primarily divided into two great divisions, viz. Saururæ and Ornithuræ, the first contains *Archaeopteryx* and possibly *Laopteryx*, the latter the rest of birds, both living and extinct." Clearly, although Beddard considered *Archaeopteryx* a bird because it possessed feathers, he considered it sufficiently different to all other birds to merit its own division (*Laopteryx* was later reclassified as a pterosaur by Ostrom in 1986).

"During the eighty five years since publication of Beddard's book, no better candidate as an intermediate between reptiles and birds than *Archaeopteryx* has appeared. Not a single intermediate with part-way wings or part-way feathers has been discovered." (p. 110)

This is an example of defining a transitional form in such a way as to eliminate the possibility of ever finding one (Cracraft 1983), since such "part-way" intermediates would not be expected. The evolution of features does not occur at the same time nor at the same rate. Some characters evolve rapidly, others more slowly, so that smooth, nicely "part-way" intermediates will not be found. During the last eighty five years, mosaic forms intermediate between *Archaeopteryx* and birds, and between *Archaeopteryx* and reptiles have been found. For example, *Mononychus* (Altangerel et al. 1993), "provides a character set of great importance to understanding primitive birds, this set can be interpreted unambiguously and it indicates a transitional position between *Archaeopteryx* and all other birds." (Milner 1993, p. 589). Also, the finding of *Sinosauropteryx* suggested that feathers may have come first and that feathered dinosaurs evolved into birds. Thus an intermediate between dinosaurs and birds would already possess feathers.

"Not a single intermediate with part-way wings or part-way feathers has been discovered. Perhaps this is why, with the passage of time *Archaeopteryx* in the eyes of some evolutionists, has become more and more 'reptile-like'! In contrast to Beddard's assessment of *Archaeopteryx*, some evolutionists today not only assert that this bird is undoubtedly linked to reptiles but that if clear impressions of feathers had not been found, *Archaeopteryx* would have been classified as a reptile. This is a gross overstatement to say the least." (p. 110-111)

The "gross overstatement" is Dr. Gish's, on several grounds.

On the link to reptiles, Beddard (1898, p. 154) states, "the general belief is in the origin of birds from some reptile stem, but there is not an absolute agreement as to precisely which group of reptiles birds are most nearly akin to. The researches of Marsh and Huxley, besides those of Cope, Seeley, Hulke and others, have led to a general acceptance of a nearer kinship with the dinosaurs than with any other group of reptiles." Also, "[i]t follows, therefore, that in sketching, at any rate, the main outlines of our scheme attention must be paid only, or chiefly, to those characters which birds have inherited from their reptilian ancestors." (Beddard 1898, p. 159). It is clear that in Beddard's view, *Archaeopteryx* was linked to reptiles and thus there is no "contrast" between his views and the modern view.

The reptilian character of *Archaeopteryx* has long been noted. In 1867, Huxley described birds as being greatly modified reptiles (Newton 1884). Indeed, the very author and book that Dr. Gish cites (Beddard 1898, p. 164) stated, "[t]here can be no doubt that the *Archaeopteryx*, far though it may have diverged from the ancestral stock, has retained more of the reptile than any other form known to us." Jordan & Kellogg (1916, p. 301) stated that, "A comparison of the ancient reptiles with the long-tailed *Archaeopteryx* and other toothed birds shows that the birds and reptiles were once scarcely distinguishable, although now so very different. Birds have feathers, reptiles do not; but there is scarcely any other permanent difference." "We may now stop talking about 'the missing link' between birds and reptiles. So much so is *Archaeornis* [the Berlin specimen of *Archaeopteryx*] this link that we may term it a warm-blooded reptile disguised as a bird." (Heilmann 1926, p.32). "*Archaeopteryx*, on the other hand, is nearly one hundred per cent reptilian, and if it were not for the feathers no-one would hesitate to regard it as purely reptilian or even dinosaurian." (Lowe 1935, p. 408). "There is in my opinion, nothing in the entire skeleton which could be pointed to as being definitely avian as opposed to dinosaurian." (Lowe 1935, p. 409). "[T]he close relationship of reptiles and birds is generally accepted and is a matter of common knowledge and history." (Lowe 1935, p. 399). "*Archaeopteryx* and *Archaeornis* then, though indubitably birds, as witnessed by their well developed and typical flight feathers, their limbs and indeed their whole skeletons, proclaim their reptilian ancestry in no uncertain

fashion." (Tucker 1938, p. 322-323).

The above quotes (see also the Lull quote below) show that Dr. Gish's claims are false. Neither the reptilian affinities of *Archaeopteryx*, nor the statements that without feathers *Archaeopteryx* would be classified as a reptile, are recent constructs.

"From the reconstruction shown in Figure 11, it is obvious that *Archaeopteryx* was very much a bird, equipped with a bird-like skull, perching feet, wings, feathers and a furcula, or wish-bone." (p 112).

Figure 1



The figure (reprinted here as Fig. 1) is taken from Lull (1940, pl. XIV). However, the caption to plate XIV cites Heilmann as the source. Dr. Gish's Figure 11 is in fact, a painting, by Heilmann, from the frontispiece of his 1926 book, *The Origin of Birds*. Lull (1940, p. 328) describes the figure, "[t]hese first birds, of which but two or three specimens have been recovered, are known as *Archaeopteryx* and *Archaeornis* (see Fig. 80 and Pl. XIV) are so reptile-like that were it not for the preserved feathers it is doubtful whether they could be surely proved to be birds." Prophetic words, since in 1940 a specimen of *Archaeopteryx* lay in the Haarlem Museum, misidentified as a pterosaur, and more recently, the Solnhofen specimen was recognised as being an *Archaeopteryx* after being originally identified as the small dinosaur *Compsognathus*.

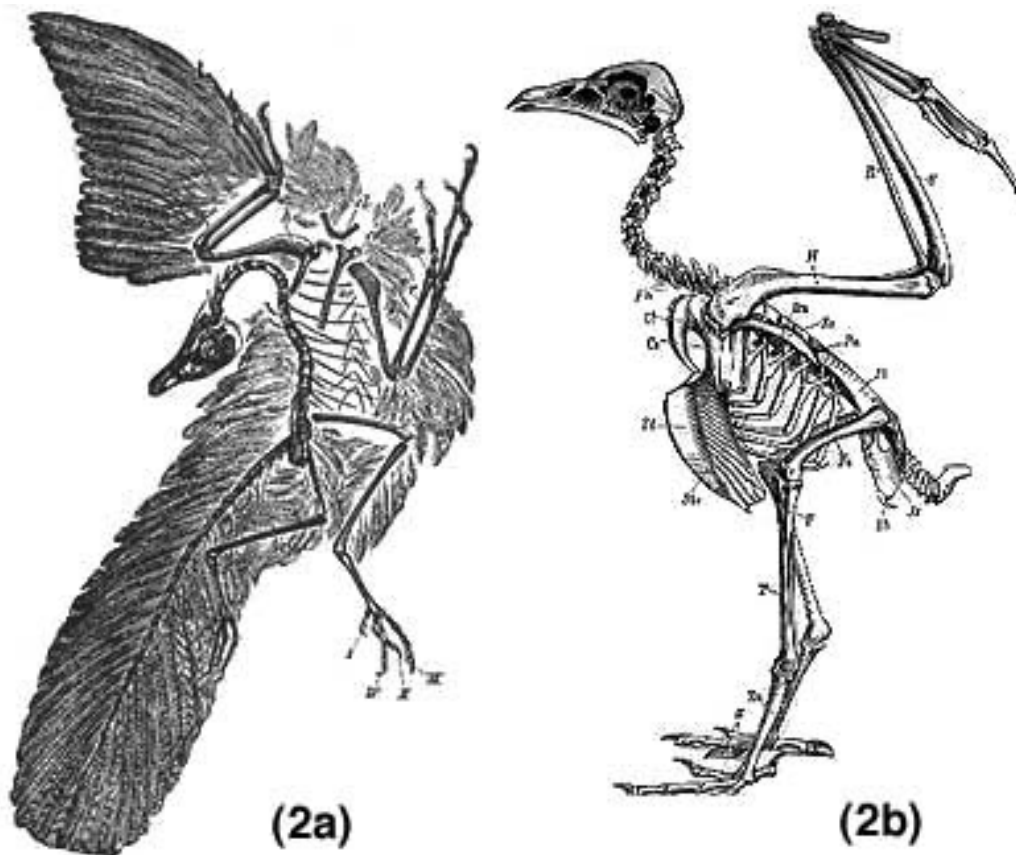
Dr. Gish not only ignores Lull's clear proclamation concerning the reptilian nature of *Archaeopteryx*, but uses a 70 year old painting of *Archaeopteryx*, **drawn as a bird**, to show that *Archaeopteryx* was "very much a bird". Presumably, by the same logic, "Barney" proves that dinosaurs were purple!

The painting does not show a "bird-like skull"; the feet are obscured by the foliage; and the furcula is an internal skeletal structure, thus making its exhibition in the painting impossible. Besides, in Heilmann's (1926) detailed analysis, *Archaeopteryx* was compared with maniraptoral dinosaurs only for the link to be rejected because it was thought that maniraptoral dinosaurs lacked clavicles (these are thought to be the precursor to the avian furcula or wishbone) (Ostrom 1976). More recently, not only have clavicles been found in dinosaurs such as *Velociraptor*, *Euparkeria* and *Ornithosuchus* (Bryant & Russell 1993), but indeed furculas have also been found in dinosaurs such as *Oviraptor* and *Ingenia* (Barsbold 1983, Barsbold et al. 1990, Bryant & Russell 1993). Therefore, possession of a furcula is no longer a character unique to birds.

The wings of *Archaeopteryx* are structurally dissimilar to those of modern birds; the wrist and finger bones are unfused (as in most theropod dinosaurs, but unlike birds and some cretaceous dinosaurs, in which the bones are fused); the wrist articulation is also much less than that in modern birds; the fingers retain claws in the adult stage (as in other theropod dinosaurs but unlike birds) and the shoulder joint is most similar to that of the theropod dinosaur *Deinonychus* and appears intermediate between theropod dinosaurs and birds (Jenkins 1993). Not only does the painting fail to document some of the characters claimed by Dr. Gish, but the painting is patently

inadequate as a scientific illustration - since it was never meant to be one. A far more accurate figure to illustrate the true nature of *Archaeopteryx* is shown in Fig. 2.

Fig. 2



This comparison between *Archaeopteryx* (a) (Parker & Haswell 1940) and a modern bird (b) (Claus 1889) shows the skeletal structure in detail and highlights the differences. This figure clearly shows that the wing and skull of *Archaeopteryx* differs from that of modern birds.

"It has been claimed that the skull of *Archaeopteryx* was reptile-like rather than bird-like. Recently, however, the cranium of the 'London' specimen has been removed from its limestone slab by Whetstone (1983). Studies have shown that the skull is much broader and more bird-like than previously thought (Whybrow 1982)." (p. 112-113)

There appears to be some confusion here, since the cranium of the London specimen was prepared out by P.G. Whybrow in 1980 and the problems encountered, the tools and conservation methods used during the preparation were detailed in a technical article (Whybrow 1982), Whetstone (1983) described and interpreted the newly exposed cranium, not its removal. It appears that Benton (1983) (the reference cited by Dr. Gish in his next sentence - see below) incorrectly attributed the description of the skull to Whybrow. Whybrow actually makes no comment on the bird-like nature of the skull. The error appears to have been repeated by Dr. Gish, who also incorrectly cites Whybrow as the source of this statement. By citing Whetstone and Whybrow Dr. Gish gives the impression that the primary literature had been consulted when, in fact, it appears not to have been. The "bird-like" comparison comes from Whetstone, "[t]he skull is much broader and more bird-like than earlier interpreted by de Beer (1954), supporting the estimates of brain size by Jerrison (1973)." (Whetstone 1983, p. 439).

The original quote is somewhat different from "...the skull is much broader and more bird-like than previously thought", since Whetstone compares the skull with de Beer's interpretation and indicated that a larger skull size had already been suggested by Jerrison in 1973. Some clarification might be in order at this point. In his description of *Archaeopteryx*, in 1954, de Beer thought that the skull was exposed along the mid-line, suggesting that half of the braincase was exposed and half buried in the matrix. This allowed de Beer to make an estimate of the brain size. However, as Jerrison (1973) pointed out, de Beer's interpretation of the mid-line was in error, and only approximately one third of the braincase was exposed. Therefore de Beer's reconstruction underestimated the brain size. Excavation of the cranium by Whybrow confirmed Jerrison's interpretation. An enlarged cranium relative to the rest of the skull is a character of birds, in reptiles the cranium is usually smaller. However, an enlarged

cranidium is not *unique* to birds. Several dinosaurs also have enlarged craniums, including *Saurornithoides* (Hopson 1980), *Stenonychosaurus* (Currie 1985) and *Troodon* (Currie & Zhao 1993). In some cases the dinosaur cranium is more bird-like than the cranium of *Archaeopteryx*.

Whetstone does describe the braincase (as opposed to the skull) of *Archaeopteryx* as, "typically avian" (p.449), however, he also describes skull features found in *Archaeopteryx* and not in birds.

"This has led Benton to state that 'Details of the braincase and associated bones at the back of the skull seem to suggest that *Archaeopteryx* is not the ancestral bird ... (Benton 1983).' Benton can only suggest that *Archaeopteryx* may be an offshoot from the early avian stem." (p. 112-113).

To reconstruct the original quote: "Details of the braincase and associated bones at the back of the skull seem to suggest that *Archaeopteryx* is not the ancestral bird, but an offshoot from the early avian stem." (Benton 1983, p. 99). However, whether or not *Archaeopteryx* is *the* ancestral bird does not detract from the fact that it is a transitional form. Transitional because it possesses characteristics in common with reptiles and also characteristics in common with birds. In other words, it possesses a mosaic of characters, some obviously reptilian (such as the long bony tail with many free vertebrae and the sacrum with 6 vertebrae; some transitional, such as the pelvic girdle and the length of the arms; and some bird-like, such as feathers and an opposable big toe). In fact, a recent study of the new, seventh, *Archaeopteryx* specimen by Elzanowski & Wellnhofer (1996) has highlighted this mosaic nature by documenting that the skull has avian (palatine + maxillary, hook shaped choanal process with a long pterygoid wing) and theropod (single vomer, and hook shaped jugal process of the ectopterygoid) traits. The transitional nature of *Archaeopteryx* is due to its morphology, not its taxonomy.

"John Ostrom has of late been the foremost proponent of a dinosaurian ancestry for *Archaeopteryx*. However, Tarsitano and Hecht have criticized Ostrom's hypothesis, claiming amongst other things that he had misrepresented the homologies of the limbs of *Archaeopteryx* and theropod dinosaurs (Tarsitano & Hecht 1980). (p. 113).

This appears to have been taken from the Benton (1983) reference noted above, suggesting that Benton, and not Tarsitano & Hecht 1980, was Dr. Gish's primary source. If this was the case, Dr. Gish has omitted the next line. The **full** statement from Benton, (compare with Dr. Gish's statement above) reads, "Finally, Tarsitano and Hecht (1980) criticized various aspects of Ostrom's hypothesis, and they considered that he had misrepresented the homologies of the limbs of *Archaeopteryx* and theropods. Thulborn and Hamley (1982), reviewing all the criticisms [of Tarsitano and Hecht and of Martin et al. 1980 - see below], however, have concluded that they are without foundation (incorrect interpretations, inconclusive evidence, persistence of primitive characters), and that they do not "seriously weaken the hypothesis that *Archaeopteryx* is closely related to theropod dinosaurs"." (p. 99-100). Dr. Gish appears to have ignored dissenting commentary on Tarsitano and Hecht 1980 to strengthen his argument.

"Martin, Stewart and Whetstone have also challenged Ostrom's claim that birds were derived from dinosaurs (Martin et al. 1980). Their analysis centers on the structure of the avian tarsus (ankle) and avian teeth. They say, 'Ostrom...has stated that the skeleton of *Archaeopteryx* is essentially identical with that of some small theropod dinosaurs' ... We think that many of these 'coelurosaurian' features are incorrectly identified. This is certainly true of the tarsal region, where *Archaeopteryx* has a pretibial bone, fibula and calcaneum of the avian type. In the dentition, *Archaeopteryx* has unserrated teeth with constricted bases and expanded roots like those of other Mesozoic birds." (p. 113)

In their 1980 paper, Martin, Stewart and Whetstone supported the theory that crocodiles were more closely related to birds than any other group. However their paper has been criticized by a number of other palaeontologists. Both Thulborn and Hamley (1982) and Cracraft (1986) commented that the analyses of Martin et al. (amongst others) were either insufficiently comparative, or that the arguments presented were not supported by rigorous phylogenetic methods. More specific criticism comes from Howgate (1984, p. 173) who, in reply to the claims made for the teeth of *Archaeopteryx*, states that, "no matter how similar are the teeth of Cretaceous birds and of crocodiles, there is little similarity of either to the teeth of *Archaeopteryx*. Of the characters supposedly indicative of close relationships only one is present, namely the lack of serrations." Thulborn & Hamley (1982, p. 623) comment that, "Martin et al. (1980, p. 89) have made a similar suggestion, maintaining that the ascending process of the *Archaeopteryx* ankle is 'primarily associated with the calcaneum'. However, these authors present a decidedly ambiguous reconstruction of the *Archaeopteryx* ankle; it shows the ascending process associated equally with the astragalus and calcaneum. The *Archaeopteryx* ankle depicted by Martin et al. (1990, fig. 1G) seems, in fact, to be structurally intermediate between the theropod ankle and the neornithiform bird ankle." By 1985, the leading proponent of the crocodylian theory, Walker, had decided that the theory was no longer tenable (Walker 1985).

Although there was disagreement over *which* reptile group were ancestral to birds, all these workers agreed that

birds were descended from a group of reptiles.

"The presence of claws on the wings of *Archaeopteryx* are often cited as evidence of a reptilian ancestry. However, there are at least three birds very much alive and well today that have claws on the wings, but no one for a moment would claim that any of these is intermediate between reptile and bird. The hoatzin (*Opisthocomus hoatzin*), a South American bird, possesses two claws in its juvenile stage. Furthermore, it is a poor flyer, with an astonishingly small keel, another feature attributed to *Archaeopteryx*. The young of the touraco (*Touraco corythaix*) an African bird, has claws on each wing and the adult is also a poor flyer. The ostrich has three claws on each wing, which, if one chose to do so, could be characterized as even more reptile-like than those of *Archaeopteryx*." (p. 113-114)

It is significant that claws are present on the fingers of *Archaeopteryx*, **in the adult form**. The hoatzin and the touraco lose the claws by the time they reach the adult condition. The claws are present in the juvenile to assist in climbing the dense foliage in which these birds live. In fact almost all birds exhibit claws to some extent, usually in the embryonic stage (e.g. Romanoff 1960), but they are lost by the time the bird hatches. As McGowan (1984, p 123) says, "in retaining a primitive reptilian feature which other birds lose just before leaving the egg [the hoatzin] is showing us its reptilian pedigree. Far from being evidence to the contrary, the hoatzin is additional evidence for the reptilian ancestry of birds."

The shoulder joint of *Archaeopteryx* is more similar to the theropod dinosaur *Deinonychus*, than to modern birds (Jenkins 1993), the shoulder joint of the ostrich is more similar to other birds than to the shoulder joint of *Archaeopteryx*. The wrist joint of the ostrich is partially fused as in modern birds, whereas the wrist joint of *Archaeopteryx* is not, as in typical reptiles. The fingers of the ostrich wing are fused together as in modern birds, the fingers of *Archaeopteryx* are free, as in typical reptiles. Thus, the wing of the ostrich can in no way be described as "even more reptile-like than those of *Archaeopteryx*."

"Another alleged reptilian feature of *Archaeopteryx* was its possession of teeth. If this is a feature derived from a reptilian ancestor, and toothed birds subsequently evolved into toothless birds, then the fossil record should produce intermediates documenting the gradual loss of teeth in birds. Not one single intermediate has ever been discovered. Some fossil birds have teeth some did not. That this should be true is not surprising since this is true of all other classes of vertebrates - fish, amphibians, reptiles and mammals. Furthermore, following the notion that the absence of teeth denotes a more 'advanced' state, then the duck-billed platypus and the spiny anteater, mammals that do not have teeth, should be considered more advanced or highly evolved than man, yet in many other ways, as previously mentioned, the duck-billed platypus and spiny anteater could be considered the most primitive of all mammals. Thus, the possession or absence of teeth proves nothing about ultimate ancestry." (p. 114)

The lack of intermediates showing tooth reduction has more to do with the lack of fossils and the way evolution operates than with any lack of such intermediates in the history of the birds. The number of Jurassic and Cretaceous bird fossils number only a few dozen at best. It is not surprising that such intermediates are not represented. However, as has been pointed out previously the expectation of finding such smooth intermediates is fallacious.

"Advanced" and "primitive" carry certain connotations. Biologists now use 'derived' for "advanced" and 'ancestral' for "primitive". However, what are considered derived characters for one group cannot be used to decide what are derived characters in another group. For instance, derived characters in snakes are (in order of appearance); reduction of limbs, loss of limbs and reduction from two to one lung, acquisition of fangs, acquisition of sensory pits. Thus from the point of view of snake evolution, humans, with their retention of limbs, retention of two lungs, absence of fangs and absence of sensory pits, are ancestral, or "primitive". As can be seen from this example what is sauce for the snake is certainly not sauce for the human! The absence of teeth is considered a derived character **in birds**, it is of little importance when deciding which characters are "advanced" **in other groups**. Thus the claim that, "the duck-billed platypus and the spiny anteater, mammals that do not have teeth, should be considered more advanced or highly evolved than man" is ludicrous, and Dr Gish should know this.

"Evolutionists have long maintained that contemporaries could not have an ancestral-descendant relationship but if related, they must have evolved from a common ancestor sometime in the past." (p. 116)

This is only true for **populations**, not for species in general. A population can be described as a (usually) reproductively isolated group of individuals which comprise a specific gene pool. Changes to that gene pool over time (the death of individuals, the birth of new individuals, mutations, etc.) all conspire to alter the genetic composition of the population so that the descendant population represents the **original** population plus the sum of the changes over time. Thus the descendant population cannot coexist with the ancestral population because the

descendant population **is** the ancestral population, plus the sum of the changes over time. However, in the vast majority of cases, one population does not comprise the entire species. There are usually multiple populations spread out geographically, some interact, some do not. What happens in one isolated population is not mirrored in the species as a whole. Indeed, changes in isolated populations is one of the engines powering speciation. Whilst the descendant population cannot be contemporaneous with its ancestral **population**, it can be contemporaneous with the ancestral **species**. A good example is the polar bear, *Ursus maritimus*.

It is thought that polar bears evolved from a population of brown bears (*Ursus arctos*) which became isolated above the Arctic Circle during one of the last major glacials. Separated from the main populations of brown bears, which remained further south, this ancestral population adapted to the cold climate (fur on the feet, white coat for camouflage during hunting, etc.), evolving into *Ursus maritimus*, whilst the more southerly populations retained the original characters. In this example, the modern polar bears cannot coexist with the ancestral population of brown bears from which they are considered to have descended, because they **are** that population, plus the sum of the genetic changes that have occurred over time. However, they can, and obviously do, coexist with the ancestral species - *Ursus arctos*. What Dr. Gish is trying to suggest, is that two contemporaneous species cannot have an ancestor-descendant relationship. As the polar bear example shows, this is not the case. Indeed ancestral species have been known to outlive their descendant species (e.g. Ozawa 1975).

"In a somewhat similar fashion, *Archaeopteryx*, although unquestionably a bird, was a mosaic which included some features that are usually termed 'reptilian.' In this respect, it is interesting to note the comment of Steven Jay Gould of Harvard University and Niles Eldredge of the American Museum of Natural History, both Ardent anticreationists. They state that, 'At the higher level of evolutionary transition between basic morphological designs, gradualism has always been in trouble, though it remains the "official" position of most Western evolutionists. Smooth intermediates between *Baupläne* are almost impossible to construct, even in thought experiments; there is certainly no evidence for them in the fossil record (curious mosaics like *Archaeopteryx* do not count)' (Gould & Eldredge 1977, p. 147). There are several important aspects of this statement, each of which seriously damages the credibility of evolutionary theory." (p.114-115)

There certainly are important aspects to the statement of Eldredge and Gould, as used by Dr. Gish, but the damage is to the credibility of creationists. The article in question is a discussion of punctuated equilibrium and how the evidence from the fossil record does not support a purely gradualistic evolutionary model. Eldredge and Gould point out that intermediates, for the most part, do not exhibit such smooth evolution, but that features evolve at differing rates. In this they were following the ideas put forward by de Beer (1969, p. 133-134; first published as de Beer 1954), who suggested that, "the statement that the animal was intermediate might mean that it was a mixture and that the transition affected some parts of the animal and not others, with the result that some parts were similar to those of one type, other parts similar to another type, and few or no parts intermediate in structure. In such a case the animal might be regarded as a mosaic in which the pieces could be replaced independently one by one, so that the transitional stages were a jumble of characters, some of them similar to those of the class from which the animal evolved, others similar to those of the class in which the animal was evolving. If now it be asked what kind of transition is shown by *Archaeopteryx*, the answer is perfectly clear. It is a mosaic in which some characters are perfectly reptilian and others no less perfectly avian."

Thus being a "mosaic" does not disqualify a form from being an intermediate, merely a *smooth* intermediate.

"Not only is it impossible at this level to find a smooth series of intermediates in the fossil record, it is impossible to *imagine* what such intermediates may have looked like (for example, try to imagine an emergent *Pteranodon* with half a jaw and half a wing!). Finally, note that Gould and Eldredge specifically exclude *Archaeopteryx* as a transitional form, terming it, as is the duck-billed platypus, a strange mosaic that doesn't count. So much for *Archaeopteryx* as an intermediate!" (p.115)

This represents a clear misrepresentation of Gould and Eldredge This probably ranks as the most famous case of the misrepresentation of scientists by a creationist author. From the previous discussion, it is obvious that Eldredge and Gould did not "specifically exclude *Archaeopteryx* as a transitional form", but merely as an example of a **smooth** transitional form. This kind of misrepresentation has led Gould to clarify his position. On transitional forms in general, he states, "since we proposed punctuated equilibrium to explain trends, it is infuriating to be quoted again and again by creationists - whether through design or stupidity, I do not know - as admitting that the fossil record includes no transitional forms. Transitional forms are generally lacking at the species level but are abundant between larger groups." (Gould 1983, p. 260). More specifically, Gould (1991, p. 144-145) states that "*Archaeopteryx*, the first bird, is as pretty an intermediate as paleontology could ever hope to find." Strange words from someone who "specifically exclude[s] *Archaeopteryx* as an intermediate"!

"Swinton, an evolutionist and an expert on birds, states: The origin of birds is largely a matter of

deduction. There is no fossil evidence of the stages through which the remarkable change from reptile to bird was achieved (Swinton 1960). Romer has said that: This Jurassic bird [*Archaeopteryx*] stands in splendid isolation; we know no more of its presumed thecodont ancestry nor of its relation to later 'proper' birds than before (Romer 1968)." (p. 114)

Both Swinton and Romer were writing some 16 and 8 years, respectively, **before** Ostrom's (1976) seminal work on the relationships between *Archaeopteryx* and maniraptoral dinosaurs. Their comments are no longer representative of current thinking on the origin of birds, nor the ancestry of *Archaeopteryx*, and were not for some 9 years **before** Dr. Gish wrote his book.

"A recent discovery by paleontologist James Jensen has dealt an especially serious blow to the claim that *Archaeopteryx* represents a transitional form between reptiles and birds. Jensen has found what he believes to be fossil remains of undoubted modern birds in rocks of the Upper Jurassic, the rocks in which *Archaeopteryx* has been found. Regardless of what one believes about the time scale or the geological column, this discovery, if ultimately verified, means that *Archaeopteryx* was a contemporary of modern birds." (p. 116)

This refers to an article by Jensen in 1981, where several avian-like bones were described, with the proximal part of a tibiotarsus were given the name *Palaeopteryx thomsoni*. However, Jensen and Padian (1989) re-identified this bone as belonging to the theropod dinosaur *Deinonychus*. Their conclusions were deliberately blunt : "No material described here is unquestionably avian. Most is pterodactyloid. Several specimens pertain to the monophyletic group formed by birds and deinonychosaurs. *Archaeopteryx* is the earliest known bird; these Morrison Formation sediments are younger than the Solnhofen limestones from which *Archaeopteryx* comes." (p. 372)

Dr. Gish states that *Archaeopteryx* was, "very much a bird" (p. 112), and, "an undoubted true bird" (p. 116). However, the classification of *Archaeopteryx* as a bird says nothing about its ancestry. As Raup (1983, p.157) says, "[t]he practicing paleontologist is obliged to place any newly found fossil in the Linnean system of taxonomy. Thus, if one finds a birdlike reptile or a reptilelike bird (such as *Archaeopteryx*), there is no procedure in the taxonomic system for labeling and classifying this as an intermediate between the two classes Aves and Reptilia. Rather, the practicing paleontologist must decide to place his fossil in one category or the other. The impossibility of officially recognising transitional forms produces an artificial dichotomy between biologic groups. It is conventional to classify *Archaeopteryx* as a bird. I have no doubt, however, that if it were permissible under the rules of taxonomy to put *Archaeopteryx* in some sort of category intermediate between birds and reptiles that we would indeed do that."

Many of Dr. Gish's assertions about *Archaeopteryx* have been shown to be incorrect. Some of these claims have been rendered invalid due to evidence found since Dr. Gish's book was first published. However, in a significant number of cases, invalidating evidence was known at the time the claims were made.

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