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Biochemistry of Dinofuzz: Feathers, Filaments, Fuzz, or Folly?

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Abstract

In recent years, paleontology has been rife with claims of feathered dinosaurs. Many of these claims are based on what can best be termed filaments, generally defined as long strands of an unknown material. Evolutionists classify them as stage one or two feathers, then claim that these filaments are made of the same structural material as modern feathers, all to show that they are, in fact, feathers. While there are so-called dinosaurs with undisputed feathers, particularly among the Dromaeosaurs, the evidence of feathers is limited to filaments or fibers in many other fossils. It is these filaments that will be the focus of this paper. Based on current data, it seems likely that true feathers are only associated with true birds, while filaments are associated with dinosaurs.

Keywords: Alpha keratin; beta Keratin; dinosaurs; birds; feathers; keratin; collagen; filaments; melanosomes

Introduction

Feathered dinosaurs have been a point of contention since the discovery of *Archaeopteryx*. Within six years, *Archaeopteryx* was variously described as a Pterodactyl, a reptile-bird crossover, a feathered reptile, and a long-tailed bird, among other things (Haynes 2022). While the Archaeopteryx question is no longer strongly disputed and even evolutionists reference it as an "early bird" (Witmer 2021, 576), the question of feathered reptiles, specifically dinosaurs, continues to draw the interest of creationists and evolutionists alike. Evolutionists have gone so far as to claim that birds are dinosaurs, a statement repeated ad nauseam by members of that community. Some creationists have also picked up the idea, claiming birds are dinosaurs in a cladistic sense (McLain 2020, 2), with a few even going so far as to add Archaeopteryx among the theropods, not the birds (Surtees 2021, 17).

If birds are, in fact, dinosaurs, then it would be expected that the data would support that claim. According to evolutionists, there is a legion of examples of dinosaurs with feathers, with one paper claiming thousands of fossils of feathered dinosaurs exist (Benton, Currie, and Xu 2021). This argument from evolutionists, however, assumes that all feathered dinosaurs are created equal. Some "feathered dinosaurs" have very obvious feathers, like *Microraptor* (Hone et al. 2010). Others, like *Psittacosaurus*, are much more contentious, looking like filaments rather than feathers (Mayr et al. 2016). This paper will examine the filaments, sometimes called dinofuzz. While no complete list exists, and given the pace of new finds, it likely would be incomplete almost immediately after publication, I identified in Table 1 22 genera of "dinosaurs" where filaments have been found.

Just identifying species with filaments does not determine the identity, whether feather, fiber, or other, of those filaments. They could, in theory, be completely unassociated with the fossils, though this is unlikely. More reasonably, they could be considered integumentary structures. Alternatively, they could be considered sub-dermal structures. Until very recently, only morphological analysis was possible. However, with the advent of paleobiochemistry, it is now possible to explore what the filaments are made of. Two hypotheses have been proposed. The first proposes that the filaments are keratinous, like modern bird feathers (Benton et al. 2019). The second, a minority position, believes they are collagen fibers (Lingham-Soliar, Feduccia, and Wang 2007). No definitive way distinguishes between the two except by applying biochemistry. However, we are beginning to see some published biochemical testing in the literature, which may help make those distinctions.

Table 1. List of organisms exhibiting dinofuzz.

Sinosauropteryx	*Yixianosaurus*	*Dilong*	*Juravenator*
Shuvuuia	*Yutyrannus*	*Sciurumimus*	*Ornithomimus*
Beipiaosaurus	*Yi*	*Eosinopteryx*	*Jianchangosaurus*
Sinornithosaurus	*Aurornis*	*Kulindadromeus*	*Xingtianosaurus*
Psittacosaurus	*Chirostenotes*	*Daurlong*	*Scansoriopteryx*

Keratin: Alpha or Beta?

Keratin comes in two major forms: alpha- and beta-keratin. The two differ, with alpha-keratin being structured in coils and beta-keratin in sheets (Saha et al. 2019, 166). Both forms of keratin are widely distributed. Alpha-keratin is found in wool, horns, hair, nails, and hooves, and beta-keratin is predominantly found in avian beaks, feathers, reptilian epidermis, and reptilian and bird claws (Shah et al. 2019, 19). However, both types of keratin are found in other places. For example, the domestic goose has both alpha- and beta-keratin in its tongue (Skieresz-Szewczyk et al. 2017). Reptile scales are also composed of both alpha- and beta-keratin (Alibardi and Toni 2006, 801). One study of genes associated with beta-keratin production in chickens found homologs in turtles, crocodiles, and even the great white shark (Cserhati 2023, 494). Obviously, the great white shark is devoid of feathers, so these genes must be doing something else.

Importantly, some claim feathers are the only structure known to consist entirely of beta-keratin (Schweitzer et al. 1999, 148). This claim has been picked up by some creationists arguing that dinosaurs have feathers (McLain, Petrone, and Speights 2018, 473). The implication is since feathers are presently the only structure made entirely of beta-keratin, then anything we find in the fossil record composed entirely of beta-keratin must also be a feather. Such an argument is very uniformitarian and breaks down upon an examination of the literature. Over a decade before creationists picked up the argument, a review of feather development casually pointed out that feathers consist of both alpha- and beta-keratin (Wu et al. 2004). The precise molecular composition of feathers varies and may depend on feather type and species or breed (Nuutinen 2017, 5). Alpha-keratins are important in feather development where they serve as foundations for beta-keratin deposition (Alibardi 2013, 194). Beta-keratin is the primary protein found in feathers (Greenwold et al. 2014), but it is not the only one. Keratin is not even the only component of a feather, making up roughly 90% of a feather with the rest being heavy metals, lipids, and nitrogenous compounds (Stettenheim 2000).

The evidence for filaments being keratinous is sparse. This is despite the abundance of fossils and the existence of multiple methods to determine the biochemical composition of the contested structures. For example, a relatively recent paper attempted to simulate the fossilization conditions and found that beta-keratin denatures to alpha-keratin in the presence of heat. Slater et al. (2023) found spectroscopic evidence that artificially fossilized feathers are comprised of alpha helices and beta sheets. However, they did not consider the effects of water or pressure, simply placing the feathers in a laboratory oven for 24 hours to prepare them for analysis. It also appears to assume that feathers are composed exclusively of beta-keratin, which as noted above is inaccurate. However, if this study accurately represents fossilization conditions, when we perform immunohistochemistry on fossil feathers, we should expect to find a mix of both alpha- and beta-keratin.

Alpha-keratin denatures under heat into random keratin coils. Moreover, in certain scenarios, a second step can occur and produce beta-domains (Wortmann et al. 2012). In water, without the application of heat and under tensile stress, alpha-keratin will transition to beta-keratin, and the transition is reversible (Wortmann and Zahn 1994, 739). Effectively, alpha-keratin denatures to less ordered beta-keratin but can renature into alpha-keratin due to the attributes inherent in its amino acid sequence. When heated in an aqueous solution under pressure, alpha-keratin denatures into partially randomized beta-keratin (Feughelman and Mitchell 1968, 1515). What this means in practice is that the particular form of keratin present in fossils is useless to determine whether filaments are feathers or not. The form of keratin is non-diagnostic. Thus, Schweitzer's premise, that if beta-keratin is the exclusive form of keratin present in a filament, it must be a feather, is falsified.

Even if it was diagnostic, however, little testing has been done. A recent review of the topic found just two published examples of beta-keratin in the dinosaur fossil record (Tahoun et al. 2022). One is irrelevant to the feather question, as it was found in a claw. The other was from *Shuvuuia* (Schweitzer et al. 1999) where only beta-keratin was found. The same fossil was reanalyzed in 2018, and no keratinous material of any kind was found (Saitta et al. 2018). At present, there is no undisputed beta-keratin found in filaments.

Most claimed examples are similar to the claims about *Kulindadromeus*, where it is assumed the filaments are keratinous based on keratin degradation patterns of keratin (Godefroit et al. 2020). Comparisons of degradation between keratin and its alternatives have not been done under fossilization-like conditions. Instead, they have been done in carefully controlled lab conditions with the application of enzymes (Bjelland, Volden, and Raa 1988). A book on ancient biomolecules even lumps keratin and collagen in the same class of difficult-to-decay molecules (Brown and Brown 2011, 106). Currently, I am unable to locate any comparisons of collagen and keratin degradation under fossilization-like conditions. However, we do not need them, as collagen has been found in a sauropodomorph dinosaur (Lee et al. 2017) and indeed in over a dozen other fossils (Thomas and Taylor 2019), showing that collagen did indeed last into the present. What this means is that neither keratin nor collagen decay rates are relevant to the identification of fossil fibers using biochemistry. Decay rates are also thus non-diagnostic of keratin.

Even if it were proved that collagen could not be preserved to the present and keratin could, it would suggest very little other than that filaments are integumentary structures. Since feathers and scales consist of both forms of keratin in varying amounts, and since keratin changes form under fossilization conditions, and since we do not know the precise conditions of fossilization for each fossil, we cannot deduce from modern biochemical detection of keratin or forms of keratin the original composition of fossil fibers.

Melanosomes

If keratin is not sufficiently diagnostic of feathers, then other alternatives must be sought. Melanosomes are found in animal cells and the primary areas of melanin production. Melanosomes have been posited as a potential indicator of feathers. Since collagen fibers, the commonly presented alternative to keratin, do not contain melanosomes, then the substance cannot be collagen if melanosomes are present.

Melanosomes are commonly purported to be detected in fossil filaments, feathers, and other structures. In one particularly famous example, color and pattern were even inferred from the purported melanosomes (Zhang et al. 2010). However, there is extensive debate in the literature over whether the purported melanosomes are actually preserved melanosomes or remnants of a bacterial biofilm (Barden et al. 2015; Schweitzer, Lindgren, and Moyer 2015; Vinther 2016). Testing these conflicting hypotheses requires special forms of microscopy. The most commonly used is scanning electron microscopy (SEM). SEM reveals capsule-like structures (Babarovic et al. 2019; Cincotta et al. 2022) resembling bacillus-shaped bacteria. Modern melanosomes found in feathers are stacked in layers and tend to be more circular than elongated (Eliason, Bitton, and Shawkey 2013; Stavenga, Leertouwer, and Wilts 2018). However, modern melanosomes have not undergone diagenesis.

A 2020 study attempted to match fossilization conditions. Sixteen separate experiments were performed on chicken feathers. In experiments where oxidation was performed, molds and impressions of degraded melanosomes formed (Slater et al. 2020). The chemical composition of these molds is unclear but they are preserved in an organic matrix and look vaguely like coccus or bacillus shaped bacteria. These molds look something like the melanosomes we see in so-called fossil feathers, but nothing like modern melanosomes. Critically, however, the researchers did not test the effects of an aqueous solution on fossilization, except in two controls where no molds formed. Also importantly, when oxidation occurred after decay and exposure to high temperatures, very few if any molds formed. In short, fossilization conditions significantly impacted whether molds formed or not.

An earlier study compared modern melanosomes to the results of feathers overgrown with bacterial biofilm, which is the common alternative explanation for the existence of molds. They found that feathers overgrown with bacteria produced structures similar to the molds (Moyer et al. 2014). Slater et al. (2020), claim that these molds cannot be bacterial in origin as they are internal to feathers, were present in undecayed feathers, and no bacteria were observed in their experiments. However, that does not solve the problem because both methods, bacteria, and models of preservation, can create molds. In other words, the existence of molds is non-diagnostic of melanosomes. They could represent the remnants of melanosomes. However, they could also represent the remnants of bacterial overgrowth on feathers. Currently, there is no way to distinguish between the two mold origins. This is especially problematic since Moyer et al. (2014) claim that they found molds on the sediment surrounding a fossil, not the fossil itself, suggesting a non-feather origin.

Another proposed method of determining whether the structures observed in fossils are true melanosomes is X-ray fluorescence (Rossi, Webb, and McNamara 2020). The problem with this method is that it depends on the elemental composition of what it examines, and the melanosome chemistry is altered by fossilization (Rossi, Webb, and McNamara 2021). The melanosome signatures will differ depending on the history of the rock, when and how it was buried, and what forces have acted on it since it was fossilized. Since we do not know the specifics of the diagenetics of the rocks in which the fossils are buried, it makes finding consistent melanosome signatures difficult to impossible.

There is a way, however, to definitively identify melanosomes in proposed tissues. That is transmission electron microscopy (TEM) (Zhao et al. 2020). Because TEM beams electrons through the sample, it can get a clear picture of what is inside, something SEM does not do. This makes TEM uniquely suited to discerning melanosomes from molds. Moyer et al. (2014), used TEM on modern feathers and found easily viewable melanosomes. TEM has been used on fossil feathers as well, and distinct melanosomes found (Carreiro Campos et al. 2019; Pan et al. 2016). However, TEM is not commonly employed in fossils (Schweitzer, Lindgren, and Moyer 2015) and to date has not been employed to determine whether filamentous structures contain melanosomes, though it has been suggested as part of the process of determining paleocolor (Roy et al. 2020).

Even if it is granted that every example of a mold is a melanosome remnant, and TEM shows that every single filamentous structure contains melanosomes, that does not prove the structures are feathers. All it proves is that the structures are integumentary, rather than subcutaneous. This is because scales, possibly including fossilized reptile skin scales, also contain melanosomes (Alibardi 2011; 2013; Rowe et al. 2013). Thus, melanosomes are non-diagnostic of feathers. They cannot be used to determine whether something is a feather or even similar to a feather. If melanosomes are present, it merely proves the substances in question are not collagen. They could have originated from either decayed skin or decayed feathers.

Collagen

There is a minority position within the evolutionist community regarding dinofuzz. Those who promote dino-to-bird evolution interpret dinofuzz as protofeathers. Finding feather-specific features would help that case. The dissenters are instead convinced that dinofuzz is not keratinous, but instead is degraded collagen fibers (Feduccia 2013). In favor of this point, taphonomic experiments show degraded skin collagen fibers resemble the positioning on the carcass, plus fibrous strand-like morphology as seen in fossils (Feduccia, Lingham-Soliar, and Hinchliffe 2005). It has also been argued that some of these fibers arise from inside the body or beneath preserved scales, making them more likely to be collagen than keratin (Lingham-Soliar 2013). As noted above, however, conclusive chemical testing has yet to be performed.

Against the possibility of the dino fuzz being collagen is argued that the fibers are simply too long. On the surface, this looks like a strong argument, as collagen fibers tend to be very short. In rats, a common model system, they average a mere 271 micrometers (Dee et al. 2003). A length of a few hundred micrometers is commonly observed in studies of collagen (Liu, Yeh, and Luo 2005). Yet in fossils, sometimes fibers over an inch long have been found. Such a length appears entirely too long to be degraded collagen fibers. However, a study done using a dead dolphin—obviously lacking in feathers—found that, during degradation, collagen relaxes and elongates, easily eclipsing the one-inch mark (Lingham-Soliar 2003). That does not prove that the dino fuzz is collagen, but it does leave the possibility open. Without biochemical testing we cannot say definitively that the filaments are not collagen. Nor can we affirm that they are collagen. All we can say is that they resemble what happens when collagen decays in fossilization-like conditions.

Intriguingly, these filamentous dinofuzz particles have been found on things other than dinosaurs. A 2019 paper discusses a pterosaur found with what the authors term "complex feather-like branching" (Yang et al. 2019). Some creationists have seized on this to argue that pterosaurs also must have been feathered (McLain 2023). Such fibers have also been found on Ichthyosaur (Lingham-Soliar and Wesley-Smith 2008) and a Mosasaur (Lindgren, Everhart, and Caldwell 2011). While the former has been alleged to be a misinterpretation of preparation marks (Smithwick et al. 2017), the latter has not been contested. Since dinofuzz is found on organisms that could not have been feathered, like Mosasaurs, then it is reasonable to question whether the land organisms where dinofuzz is found were feathered also.

What is Dinofuzz Made Of?

The short answer to the above question is that we do not know. No one knows for certain. What we have now are competing theories about dinosaur origins being imposed on filaments in the rock record of unknown composition. That is all. There has been no undisputed chemical testing performed. And even if the chemical tests were to be performed, they would not answer the ultimate question: is it a feather? The biochemical composition of a feather is not uniform, so simply looking for beta-keratin to the exclusion of all else will not work. It is possible a battery of tests, including spectral analysis, protein antigen testing, SEM, TEM, and immunohistochemical analyses could be developed to determine whether a structure's residual biochemistry resembles what one might expect to remain in a long-buried feather. However, such standardized testing does not currently exist. Were it to be developed, it would have to be standardized against modern and fossil feathers before being deployed on the ambiguous filaments. Even this assumes that the structure of feathers in the present is analogous to the feathers of the past, which may or may not be true.

What this means in effect is that the composition of dinofuzz is unknown at present. Much of it morphologically resembles decayed collagen fibers and many of the so-called melanosomes are questionable at best. However, all the evidence is not in. Asking the jury to deliver a verdict before they have heard all the evidence is less than responsible. Such is the case here. We simply lack enough evidence to state whether the fossilized dinofuzz is keratin, collagen, or something else. Therefore, we cannot empirically determine if it is a feather, a degraded scale, or subcutaneous tissue. The best morphological fit at present seems to be subcutaneous tissue, but morphology alone cannot answer this question. Biochemistry must and, as yet, biochemistry has not provided a clear answer. That is an area where creationists can take the lead in doing good science. There is a plethora of unanswered questions in this area, questions secularists have not yet explored.

From a biblical perspective, there is little doubt that dinosaurs and birds are separate groups, having been created on separate Creation days. With no sure test for fossil feathers currently available, it is reasonable to question the evolutionary assumption that dinosaurs had feathers. Currently, the only evidence for such a claim is wishful thinking and imaginative comparisons. When evolutionists make a claim about the naturalistic origin of life, backed by wishful thinking and misconstrued tests, creationists are rightly skeptical. Such ought to be the same in this instance. Creationists would do well to be skeptical of any unsubstantiated claim originating from the evolutionary community until it is properly vetted. In this instance, vetting, in the form of biochemical testing, is non-existent, and thus claims of feathered dinosaurs should be viewed with open minded skepticism.

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