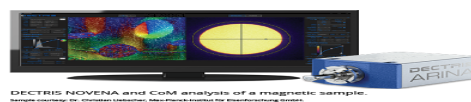


An Organic Food Web Exists within the Bioapatite Inorganic Bone Surfaces of Cretaceous Dinosaurs Edmontosaurus, Triceratops and Nanotyrannus

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An Organic Food Web Exists within the Biapatite Inorganic Bone Surfaces of Cretaceous Dinosaurs *Edmontosaurus*, *Triceratops* and *Nanotyrannus*

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The discovery of soft tissues in dinosaur bones remains controversial regardless of our understanding of its permanence or state of preservation. Ancient soft tissue in dinosaurs is of great interest worldwide: workers are reporting regularly on new findings [1]. Even trade publications are no stranger to these controversies [2]. However, acquiring the facts about soft tissues within fossil bones is certainly hampered by the traditional view that dinosaur (and other) interred ancient bone fossils are permineralized; i.e. turned to stone.

Many reports clearly show that soft, stretchy material exist *in situ* in dinosaur bones, without prior exposure to laboratory reagents, especially fixatives even in the presence of at least some mineralization [3-5]. Interestingly, the first three reports from the most recognized ancient tissue researcher begins with the words *soft tissue*.

It seems that a major emphasis of ongoing research and discussions have centered on this odd fact: much of what remains of dinosaurs is *soft* [6-10]. Furthermore these soft structures are found within bone that is easily decalcified (broken down) using a routine hospital protocol [3-5,7,9-10]. Permineralization of these remains seems rare or at least selective in the majority of the dinosaur bones recovered [3-5,7]. (See also van de Reest AJ and Currie PJ 2020 *Cret. Res.* 109:104370, which details a 95% presence of pliable blood vessels in over dozen *museum* specimens from Dinosaur Provincial Park, Alberta).

Soft cells, soft nerves, soft vessels and soft fibrillar bone seem incompatible with creatures that are of Cretaceous age or older. The question might arise, "what else is *soft* inside these bones?" We do know that living microbes are present, in dinosaur bones, particularly bacteria [1,8,11]. We also know that these communities of bacteria differ significantly from less robust communities living in surrounding soil. "The fossil had become a habitat for an unusual community of microbes that is not found in the surrounding sediment or above ground," [11]. This would suggest that the more robust internal bacterial communities do metabolize what they need from the resources existing *inside* the bone. The authors confirm that the inner bacterial community is in fact metabolizing endogenous organics [ibid]. How did these unusual communities get there if they cannot be found in surrounding sediments or at the surface? How have they survived for so long and on what are they feeding? Whatever the answers are, it is established that vibrant bacterial communities live within dinosaur bones.

Regarding fungi within dinosaur bones, reports seem rare [3,4,8, 11]. Workers have shown the presence of easily distinguishable fungal hyphae in decal solutions of a *T rex* femur which also yielded robust and soft dinosaur vessels [3]. The same group later reported fungus intruding into fossil Emu and Moa bones but not into the *T rex* bones analyzed [4]. Other workers illustrated fungal hyphae and plant roots under SEM showing hyphae intruding deeply into fossil *Triceratops* bone that was partially decalcified [8]. Abundant mineralized fungal hyphae and mycelia are reported from canals of Cretaceous long bones collected in the Gobi desert, but no extant fungal elements were discovered [12]. Moreover, a comprehensive study of predators and scavengers on over 40 individual dinosaur bones listed many accomplices, but microorganisms were not studied [13]. Large fungal and nematode communities within hadrosaur bones from Hell Creek were recently reported by Peterson and Armitage [14]. Fungal hyphae were also detected in the most recent study of *T. rex* decalcification (MOR1126) [1].

The bone fungus we found is blunt and rugose and only became exposed after partial demineralization of a thick bone shard (Figure 1, arrows). It is unlikely that the hyphae are emanating from the thin crack in the bone (probably an artifact of processing). Our light micrographs reveal that the fungus is actually growing out of the organic clot appressed along the inorganic walls of the hydroxyapatite bone canal (Figure 4 arrows). There is therefore substantial evidence of extant fungal infestations deep within dinosaur bones. It seems to us that the fungi might support populations of fungivorous nematodes in the bone.

In the summer of 2024, we successfully trapped wild fungivorous nematodes from soils surrounding interred bones in Glendive, MT. One worm was collected from a small shard of *Triceratops* bone after immersing in distilled water. We used in soil fruit traps, individual soil samples and shards of bone with the Baermann funnel method and liberated 3 total worms [14] (Figure 2). Photomicrographic video of the worm extracted from *Triceratops* shows it actively writhing periodically (not shown).

We propose that fungi (just like bacteria) are consuming organics that still exist in the bones at Glendive and this attracts extant fungivore and bacterivore nematodes. We hope to confirm that bacterivore nematodes are present within the hydroxyapatite of bone.

Insects have are also known to predate upon buried bones [15,16], dinosaur bones included [17]. Much work has been undertaken to elucidate these ichnofossils (traces tracks and burrows) left by insects on and within dinosaur bones [ibid]. Insects such as termites, moths and particularly dermestid beetles often leave pits, scratches and pupal or brood chambers in dinosaur bone. However studies reporting the presence of insect parts are very rare. At this symposium we report our discovery of beetle cadavers molts and mandibles from our decalcification solutions of dinosaur bones from Glendive (Figure 3).

These evidences of intra-bone cadavers and mandibles appear fresh, unabraded, and unscuffed. We therefore we interpret them as recent, from extant beetles inside the bone.

Based on these results it appears that we have uncovered a complex network of interconnecting and overlapping food chains showing feeding relationships within a community. *This is the definition of a food web.* If bacteria and fungi are decomposing endogenous organics in dinosaur bones, resulting in a food chain that attracts bacteriovore and fungivore nematodes, what other members of this food web might exist?

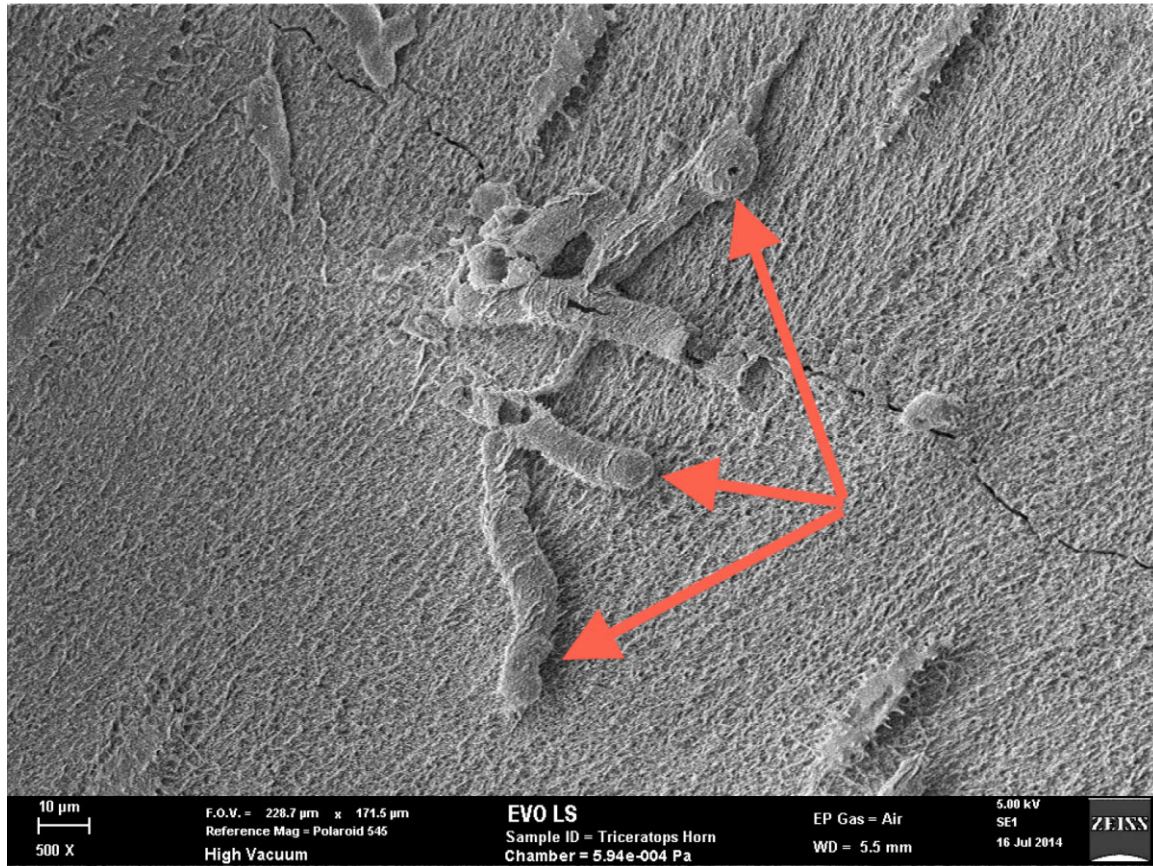


Fig. 1. SEM of partially decalcified *Triceratops* horn shard. Red arrows point to inner bone fungus. Note osteocyte cells lying on fibrillar bone. Scale bar = 10 μ .

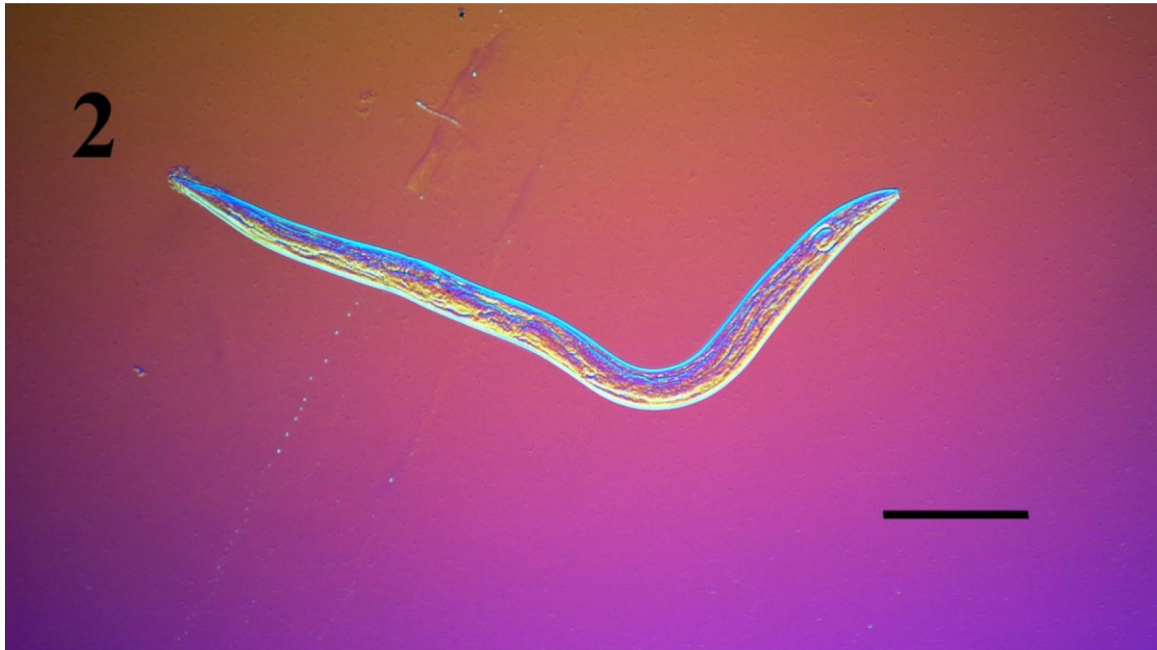


Fig. 2. Fungivorous nematode collected by bone soak Baermann funnel method, DIC. *Triceratops* horn shard, Glendive, MT. Scale bar = 75 μ .

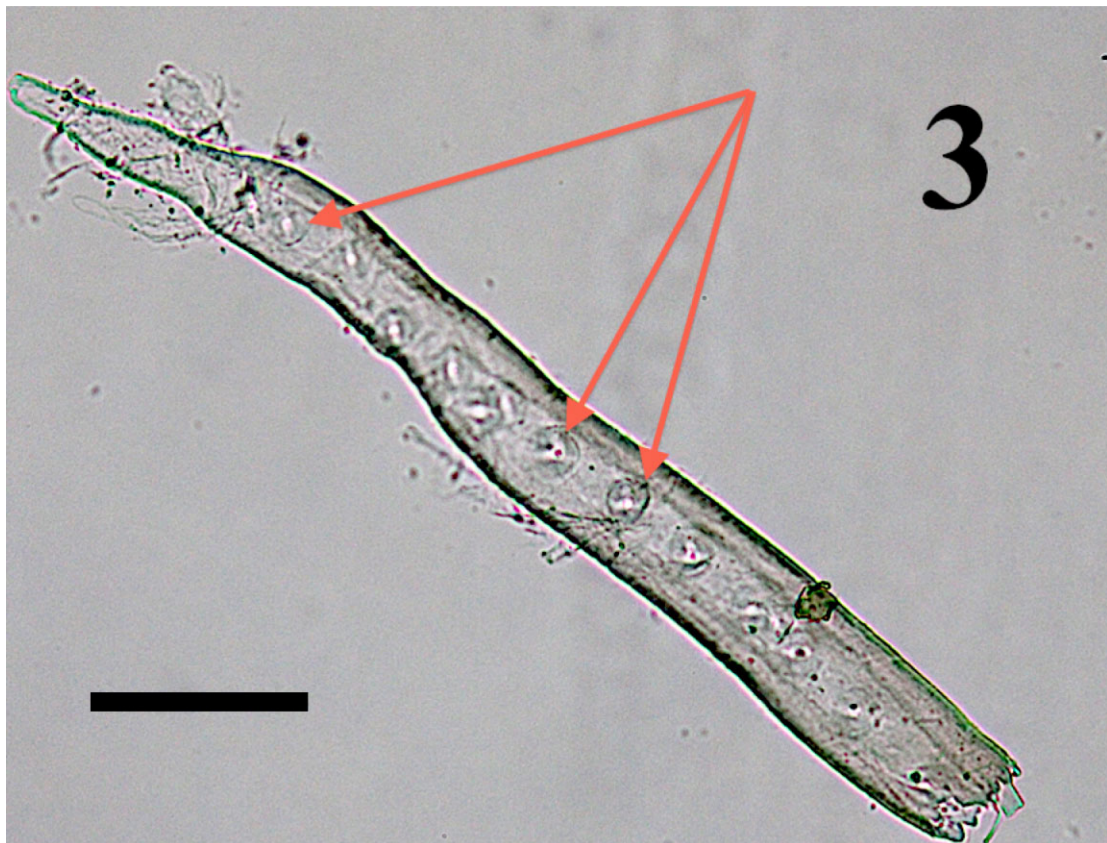


Fig. 3. Insect molt cast from demineralized dinosaur bone. Light micrograph. Note breathing spiracles along wall of molt (red arrows). Scale bar = 10 μ .

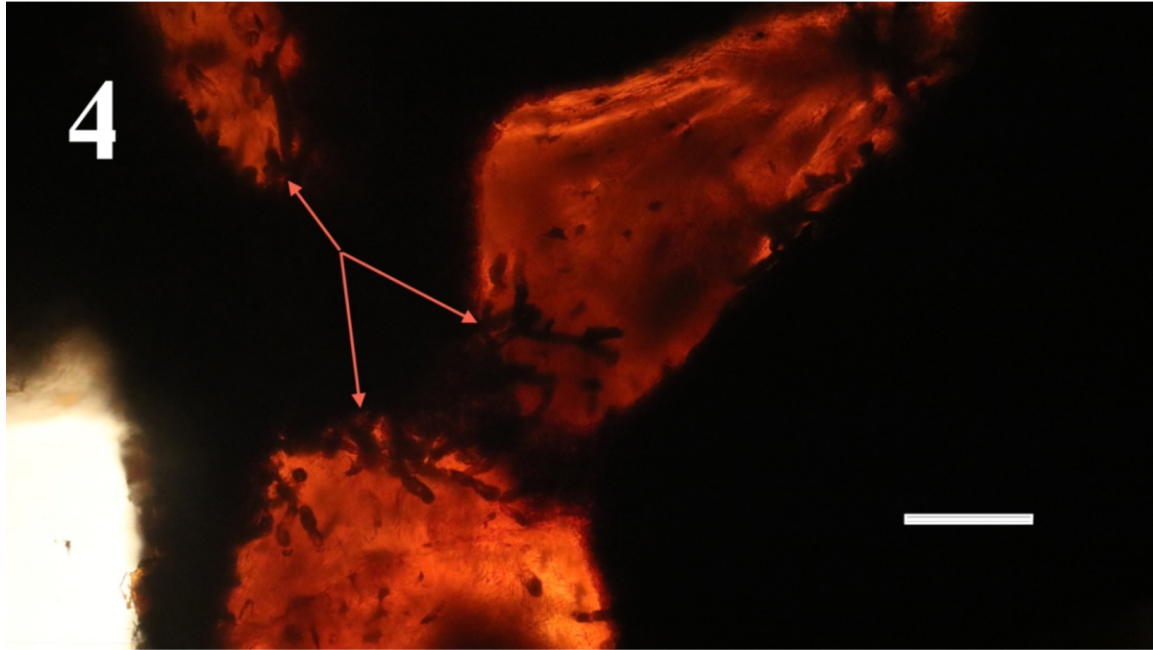


Fig. 4. Fungal hyphae emanating from clot material adhering to inorganic bone canal wall. Thin section of *Edmontosaurus* jaw. Scale bar = 10 μ .

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