List of Biomaterial Fossil Papers (maintained)

Peer-reviewed journal articles on surviving endogenous biological material including tissue and DNA.

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researchgate.net/project/biomaterial-fossils-list-at-bflistrsrorg bflist.rsr.org

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T. rex: 

icr.org/fresh-fossils icr.org/brian_thomas
rsr.org/dino-soft-tissue rsr.org/bob-enyart

Newly added papers & biomaterial dated 250M+ years in red.

#	Year	**Description** (gray cells for dinosaur remains)	**Age**	**Authors, Publication, etc.**	**Link**	**Notes / Excerpts** (papers do not qualify for this page if they report only soft tissue imprints or permineralization; they must document extant endogenous biological materal)			Vol (Issue), pp, DOI, etc.	Dinosaur papers:
116	2021	Parts of proteins in titanosaur eggshell	~70MY	Dhiman et al. Protein fragments in late Cretaceous eggshell, Paleontology	onlinelibrary.wiley.com/doi/pdf/10.1111/pala.12	"...we provide incontrovertible evidence for the preservation of proteinaceous moieties in Maastrichtian dinosaur eggshell using pyrolysis-GC9GCTOFMS."			7/13/2021:1-11	dino
115	2021	Nerve fragments, sheath, from *Triceratops* bone	65MY	Armitage, First Report of Triceratops Occipital Condyle Nerves, Microsc Today	cambridge.org/core/journals/microscopy-today	"In this study we provide evidence of nerve fragments, characterized by a double helical wrapping of collagen fibers, from a Triceratops condyle collected at the Hell Creek Formation, MT."			29(2):20-25	dino
114	2020	Dino eggshell peptide bonds and chelating ligands	200MY	Norell, Wiemann, et al. The first dinosaur egg was soft, Nature	nature.com/articles/s41586-020-2412-8	"Hard eggshells preserve PFPs still-intact peptide bonds and contain abundant chelating ligands"; PFP, protein fossilization products, is a term Wiemann, Yang, & Norell introduced in 2018			583:406–410	dino
113	2020	*Hypacrosaurus* cartilage; apparent chromosomes	75MY	Bailleul, Schweitzer et al. Evidence of proteins, chromosomes, DNA, NS Rev	academic.oup.com/nsr/advance-article/doi/10.	"Isolated [hadrosaur] chondrocytes... positive response to two DNA assays"; "Collagen II is not produced by microbes"; In supplemental material: "chromosomes are very clear"			doi.org/10.1093/nsr/nwz206	dino
112	2020	*Triceratops* blood clots, veins, valves, nerve fibers	65MY	Armitage, Solliday, Dinosaur blood clots in vessel canals, Microscopy Today	cambridge.org/core/journals/microscopy-today	"dinosaur neurovascular bundles travel as a triad of veins, vessels, and nerve fibers, as in other vertebrates." Re: Schweitzer and heme, "free iron was unavailable, at least in these... bones"			28(5):30-38 Sept 2020	dino
111	2019	Permian marker plant's lignin biopolymers	~255MY	Tewari et al. Biomarker signatures of *Glossopteris* plant. Palaeogeography PP	sciencedirect.com/science/article/abs/pii/S003				531, Part B	
110	2019	*T. rex* cortical bone blood vessel structures	66MY	Boatman, Schweitzer et al. Tissue and protein preserved in *T. rex*, N Sci Rep	nature.com/articles/s41598-019-51680-1	Full title: "Mechanisms of soft tissue and protein preservation in Tyrannosaurus rex." Preemptive criticism: rsr.org/biomaterial-fossil-proposed-mechanisms			SR9:15675	dino
109	2019	Precambrian chitin (from glucose) from fungi walls	**~950MY**	Loron et al. Early fungi from the Proterozoic era in Arctic Canada, Nature	nature.com/articles/s41586-019-1217-0				10.1038/s41586-019-1217-0	
108	2019	Partially unracemized feather amino acids in amber	99MY	McCoy, Collins et al. Amino acids from feathers in amber, Scientific Reports	nature.com/articles/s41598-019-42938-9	"Burmese amber sample shows less racemisation than the Baltic amber sample which is unexpected given that Burmese amber ~99 Ma is approximately twice as old as Baltic amber ~44 Ma"			9(6420):1-8	
107	2019	Sugars from Cretaceous fungi in mudstones & coal	~25-70MY	Marynoswki et al. Indicators of fungal metabolism, Int'l J of Coal Geology	sciencedirect.com/science/article/abs/pii/S016	"co-occurrence of trehalose, mannitol and arabitol in the sedimentary rocks... suggests their fungal origin, because these... are major compounds present in most modern fungi"			May 2019, pp 51-61	
106	2019	Lebanon's hagfish fossil with skin protein remnants	~100MY	Miyashita, et al. Hagfish from the Cretaceous Tethys Sea, Proc. Nat'l Acad Sci	pnas.org/content/116/6/2146	"The chemical mapping is consistent with the fact that a major component of hagfish slime is tightly coiled, mucin-coated α-keratin threads"		icr.org/article/ancient-fossil-still-has-hagfish-slime-residu	10.1073/pnas.1814794116	
105	2019	Edmontosaur osteocytes, blood vessels, collagen	66MY	Ullmann, Nellermoe et al. Patterns of cellular preservation Cretaceous Res.	sciencedirect.com/science/article/pii/S0195667	In vast Edmontosaurus bonebed, each specimen yields abundant osteocytes, blood vessels, and collagen; surprisingly, there's no correlation between burial depth nor spongy or dense bone.			99:1-13	dino
104	2019	*Anchiornis* (small dinosaur) feather keratin	160MY	Pan, Schweitzer et al. Direct evidence of feather molecular evolution PNAS	pnas.org/content/early/2019/01/23/181570311	"Keratins have [enhanced] preservation potential over other nonbiomineralized tissues." This is presumed apparently because feathers are not normally saturated in hemoglobin. See rsr.org/ms.			10.1073/pnas.1815703116	dino
103	2018	Flexible portions of skin layers, red-brown liver trace	180MY	Lindgren, Schweitzer et al. Icthyosaur homeothermy and crypsis, Nature	nature.com/articles/s41586-018-0775-x	"still-flexible remnants of the original scaleless skin... epidermal and dermal... cellular, sub-cellular biomolecular constituents... also possible internal organ trace... red-brown liver... in rib cage."			564:359–365	
102	2018	Bacteriochlorophyll (still pink & biological) pigments	**1.1GY**	Gueneli et al 1.1-billion-year-old porphyrins, Proc. Nat'l Acad of Sciences	pnas.org/content/115/30/E6978	Senior lead researcher Assoc Prof Jochen Brocks, Australian National University, "What we've found is the [so far] oldest biological colour."		theguardian.com/science/2018/jul/09/scientists-discove	doi.org/10.1073/pnas.1803866115	
101	2018	Bivalve organics in the late Cretaceous	66MY	Myers et al. Cretaceous Pinna organic matrix & shell microstructure, Geology	pubs.geoscienceworld.org/gsa/geology/article-	"interprismatic proteins are preserved with intact peptide bonds, and suggest an abundance of the amino acid glycine"		icr.org/article/more-exceptional-preservation-of-organic-	46 (8):711-714	
100	2018	*Dickinsonia* lipid biomarkers showing cholesteroids	**558MY**	Bobrovskiy et al. Steroids establish Ediacaran *Dickinsonia* as animal, Science	science.sciencemag.org/content/361/6408/124	"lipid biomarkers extracted from organically preserved Ediacaran macrofossils... Dickinsonia... produced cholesteroids..." But Google: Günter Bechly dickinsonia, for his rebuttal.			361(6408):1246-1249	
99	2018	Starch (a polysaccharide) in a forest deposit	280MY	Liu et al. Fossil starch reveals early plant–animal mutualism, Geology	pubs.geoscienceworld.org/gsa/geology/article/	"ultrathin sections of the megaspores indicate that they may have been produced after the megaspores were fertilized" and "used to attract and reward animals... for megaspore dispersal"			46(5):423-426	
98	2017	Sea turtle muscle protein, beta-keratin, pigment	54MY	Lindgren, Schweitzer et al. Juvenile sea turtle, Nature: Scientific Reports	nature.com/articles/s41598-017-13187-5	3-inch long turtle (as with entire list, no report that it was found coated in biological iron)			7(13324):1-13	
97	2017	Bird preening (sebaceous) gland still containing oil	48MY	O'Reilly et al. Uropygial gland lipids in 48MY-old bird, Proc. Royal Soc. B	rspb.royalsocietypublishing.org/content/284/18	icr.org/article/10401			284(1865)	
96	2017	Dinosaur eggshell color by protoporphyrin/biliverdin	66MY	Wiemann et al. Dinosaur egg color: oviraptors laid blue-green eggs, PeerJ	peerj.com/articles/3706/	"Preserved dinosaur egg color... pushes the current limits of the vertebrate molecular and associated soft tissue fossil record..."			PeerJ 5:e3706	dino
95	2017	Ginkgo leaves "full of organic molecules"	200MY	Vajda et al. Molecular signatures of leaves unexpected, Nature Eco & Evol	nature.com/articles/s41559-017-0224-5	icr.org/article/fossil-plants-contain-original-molecules			s41559-017-0224-5	
94	2017	Melanin in nodosaurus dino (and other biologicals)	112MY	Brown et al. Exceptionally preserved armored dinosaur, Current Biology	cell.com/current-biology/fulltext/S0960-9822(1				27(16):2514-2521.e3	dino
93	2017	Tick-related mammalian "red blood cells"	20-45MY	Poinar, Tick erythrocytes reveal piroplasms, Journal of Medical Entomology	academic.oup.com/jme/article/3073510/Fossili				54(4):895-900	
92	2017	*Nothosaurus* coracoid vessel, hydroxyproline	~225MY	Surmik et al. Intraosseous fossilized middle Triassic soft tissue, Sci of Nature	ncbi.nlm.nih.gov/pubmed/28280877				104(3-4):25	
91	2017	Reconfirmation of B. canadensis dinosaur collagen	80MY	Schroeter, Schweitzer et al. Expansion of sequence, J of Proteome Research	pubs.acs.org/doi/abs/10.1021/acs.jproteome.6				16(2):920-932	dino
90	2017	Lufengosaurus rib collagen	195MY	Lee et al. Collagen in an early Jurassic sauropod, Nature Communications	nature.com/articles/ncomms14220				ncomms14220	dino
89	2016	Proteinaceous amide groups in chert	**1.88GY**	Alleon, Bernard et al. Molecular preservation of 1.88 Ga... organic..., Nature	nature.com/doifinder/10.1038/ncomms11977				ncomms11977	
88	2016	Early Triassic reptile blood vessels, etc.	247MY	Surmik et al. Organic Matter from Triassic Reptile, PLoS ONE	journals.plos.org/plosone/article?id=10.1371/jo	icr.org/article/organic-residue-247-million-years-old/			pone.0151143	
87	2016	*Psittacosaurus* dinosaur skin now also has keratin	130MY	Vinther et al. Camouflage in an Ornithischian dinosaur, Current Biology	cell.com/current-biology/pdf/S0960-9822(16)3	news.nationalgeographic.com/2016/09/dinosaur-camouflage-fossil-find/			26:2456–2462	dino
86	2016	Beta-keratin in oviraptor dinosaur claw	75MY	Moyer, Schweitzer et al. The claw of nesting dinosaur, Proc Royal Society B	rspb.royalsocietypublishing.org/content/283/18				283(1842):1-7	dino
85	2015	Hadrosaur "blood vessels from *Brachylophosaurus*"	80MY	Cleland, Schweitzer et al. Blood vessels characterization, J Proteome Res	pubs.acs.org/doi/10.1021/acs.jproteome.5b00	The first paper to sometimes drop qualifier "like" as in "blood-vessel-like" and state clearly "dinosaur vessels", etc.			14(12):5252-5262	dino
84	2015	Dinosaur collagen and red blood cells	75MY	Bertazzo, et al. Fibres and cellular structures..., Nature Communications	nature.com/ncomms/2015/150609/ncomms83				ncomms8352	dino
83	2015	Dinosaur melanosomes and pigment	150MY	Lindgren et al. Molecular composition of Jurassic feathers, Scientific Reports	nature.com/articles/srep13520				srep13520	dino
82	2015	A pterosaur's orange claw material	150MY	Hone et al. A specimen of *Rhamphorhynchus* with soft tissue, PeerJ	peerj.com/articles/1191/	"The claw sheathes seen here do seem to be genuinely preserved soft tissues given their clear colour and texture differences to the surrounding matrix."			PeerJ 3:e1191	
81	2014	Precambrian multicellular animals (metazoans)	530MY	Moczydłowska et al. Biogeochemistry of Ediacaran Metozoa, J of Paleontology	cambridge.org/core/journals/journal-of-paleont				88(2):224-239	
80	2014	Bird, marine reptile, mosasaur, icthyosaur pigments	55-190MY	Edwards et al. Pigments through time [survey], Pigment Cell Melanoma Res.	onlinelibrary.wiley.com/doi/epdf/10.1111/pcmr.1	"...so far the data show that original chemical retention may be more common than previously believed."			27(5):684-685	
79	2014	Turtle, mosasaur, and icthyosaur eumelanin	55-190MY	Lindren et al. Pigmentation... melanism in extinct marine reptiles, Nature	nature.com/nature/journal/v506/n7489/full/natu				506(7489):484-488	
78	2014	Gastropod egg capsule chitin	200MY	Wysokowski et al. Chitin in 200-million-year-old egg capsules, Paleobiology	cambridge.org/core/journals/paleobiology/artic	What's an egg capsule? See Wikipedia for "Otheca" and shark cases at:	en.wikipedia.org/wiki/Egg_case_(Chondrichthyes)		40(4):529-540	
77	2014	Extinct aquatic bird *Gansus* feather melanosomes	~125MY	Moyer, Schweitzer et al. Melanosomes or Microbes, Scientific Reports	nature.com/articles/srep04233	"have refined the age of the Xiagou Formation lacustrine beds to the early Aptian stage"			srep04233	
76	2013	*Triceratops* osteocytes; soft sheets of fibrillar bone	65MY	Armitage, Anderson, Soft sheets of horn fibrillar bone, Acta Histochemica	sciencedirect.com/science/article/pii/S006512	Published in Italy (Acta Histochemica)	Hear interviews with the authors at:	rsr.org/triceratops	115(6):603-608	dino
75	2013	*Vauxia* sea sponge chitin	**505MY**	Ehrlich et al. 505-million-year old chitin in *Vauxia gracilenta*, Scientific Reports	nature.com/articles/srep03497				srep03497	
74	2013	Lufengosaurus embryo bone protein	190MY	Reisz, Embryology of early Jurassic dino with evidence of organic... Nature	nature.com/articles/nature11978	nature.com/news/oldest-dinosaur-embryo-fossils-discovered-in-china-1.1277	False: Earliest 'known' organic remains of a terrestrial vertebrate. See 1966 below.		496(7444):210-214	dino
73	2013	Signature of blood in mosquito gut	46MY	Greenwalt et al. Hemoglobin-derived porphyrins. Proc. Nat'l Acad of Sci	pnas.org/content/early/2013/10/08/131088511	smithsonianscience.org/2013/10/blood-molecules-preserved-for-millions-of-years-in-abdomen-of-fossil-mosquito/?utm_medium=referral&utm_source=pulsenews			10-14-2013	
72	2013	Dino DNA & proteins actin, tubulin, PHEX, histone	66-80MY	Schweitzer et al. Analyses of dino osteocytes support endogenous... Bone	ncbi.nlm.nih.gov/pubmed/23085295	"All of our assays require at least 4 or more bases to generate reactivity... each capitalizing on different aspects of the chemistry of DNA... [show] identical patterns..."			52(1):414-23	dino
71	2013	Biological material in crinoids	350MY	O'Malley et al. Taxon-specific organic molecules, Geology	geology.gsapubs.org/content/early/2013/01/17				41(3):347-350	
70	2012	Cuttlefish ink sac	160MY	Glass et al. Jurassic period eumelanin pigment, Proc. Nat'l Acad. of Sciences	pnas.org/content/109/26/10218.abstract?sid=b	web.archive.org/web/20120525074302/http://news.nationalgeographic.com/n			109(26):10218-10223	
69	2012	Archaeopteryx black melanin organosulpher residue	150MY	Carney et al. Color and nature of Archaeopteryx feather, Nature	nature.com/articles/ncomms1642	"not due to precipitation of the inorganic mineral"			ncomms1642	
68	2012	Jurassic turtle osteocytes	145MY	Cadena, Schweitzer, Osteocytes preservation from the Jurassic, Bone	thebonejournal.com/article/S8756-3282%2812				51(3):614-620	
67	2011	Chitin arthropod (scorpion) and eurypterid proteins	417MY	Cody et al. Molecular signature of Paleozoic chitin-protein complex, Geology	geology.geoscienceworld.org/content/39/3/255				39(3):255-258	
66	2011	Type 1 collagen in Cretaceous mosasaur humerus	~70MY	Lindgren et al. Microspectroscopic evidence of bone proteins, PLoS ONE	journals.plos.org/plosone/article?id=10.1371/jo	Its "4.68%±0.1 of modern 14C" attributed to contamination yet Nature 2017 on "Carbon fixation" finds cynobacteria get "virtually all" its carbon from the bone; not the atmosphere; rsr.org/14c			6(4): e19445	
65	2011	Endogenous *Mississaepia* cuttlebone chitin sheets	34MY	Weaver et al. Late Eocene cuttlefish B-chitin consistent organics, PLoS ONE	dx.plos.org/10.1371/journal.pone.0028195				pone.0028195	
64	2011	Lizard tail skin breakdown products	50MY	Edwards et al. Tissue preservation in 50MY-old reptile skin, Proc Royal Soc B	rspb.royalsocietypublishing.org/content/early/2				rspb.2011.0135	
63	2011	Type I collagen in *T. rex* and hadrosaur dinosaurs	68MY	San Antonio, et al, Dinosaur peptides... mech of protein survival, PLoS ONE	plosone.org/article/info%3Adoi%2F10.1371%2				pone.0020381	dino
62	2011	Bird feather pigment from *Confuciusornis sanctus*	120MY	Wogelius et al. Biomarkers for eumelanin pigment in fossil record, Science	science.sciencemag.org/content/333/6049/162				333(6049):1622-1626	
61	2010	Stegosaurus plate keratin	~150MY	Christiansen et al. Stegosaur impressions, Swiss Journal of Geosciences	researchgate.net/publication/226416413_Exce				103(2):163-171	dino
60	2010	Messel feather highly reflective nanostructure	40MY	Vinther et al. Structural coloration in a fossil feather, Roy Soc Biology Letters	ncbi.nlm.nih.gov/pmc/articles/PMC2817243/	Published online Aug. 26, 2009. "The keratin... has degraded... the preserved layer of melanosomes is apparently highly reflective."			6(1):128-131	
59	2010	*Archaeopteryx* feather shaft original chem remains	150MY	Bergmann et al. *Archaeopteryx* feathers & bone chemistry, Proc Nat Acad Sci	ncbi.nlm.nih.gov/pmc/articles/PMC2889062/?t				107(20):9060-9065	
58	2010	*Sinosauropteryx* compsognathid dino melanosomes	125MY	Zhang et al. Fossilized melanosomes and the colour of dinos & birds, Nature	nature.com/nature/journal/v463/n7284/full/natu				463:1075-1078	dino
57	2010	Hadrosaur biomolecules, collagen & other proteins	80MY	Peterson et al. Microbial biofilms [&] soft tissue in archosaurs, PLoS One	journals.plos.org/plosone/article?id=10.1371/jo	"compelling evidence countering the argument that these structures are simply microbial biofilm."			pone.0013334	dino
56	2010	*Psittacosaurus* dinosaur skin color	125MY	Lingham-Soliar et al. Integument & color of a ceratopsian, Science of Nature	springerlink.com/content/3wnn717728x963n2/	Published in Germany (Naturwissenschaften)	rspb.royalsocietypublishing.org/content/275/1636/775.abstract	Psittacosaurus sample used in PRSB 275:775-780.	97:479-486	dino
54	2010	Mammal hair in amber	100MY	Vullo et al. Mammalian hairs in early Cretaceous amber, Science of Nature	adsabs.harvard.edu/abs/2010NW.....97..683V				97(7):683-687	
53	2009	Hadrosaur vessel proteins, sequenced collagen	80MY	Schweitzer et al. Biomolecular... protein sequences of hadrosaur, Science	sciencemag.org/content/324/5927/626.abstrac				324(5927):626-631	dino
52	2009	Hadrosaur skin cell structures/macromolecules	66MY	Manning et al. Chemistry in a mummified hadrosaur, Proc. Royal Society B	rspb.royalsocietypublishing.org/content/276/16	Related: Hadrosaur their teeth were more advanced than today's grazers.	rsr.org/soft#teeth		276:3429-3437	dino
51	2009	Salamander muscle, whole	18MY	McNamara et al. Organic... fossil musculature with ultracellular detail, P RS B	rspb.royalsocietypublishing.org/content/277/16				277(1680):423-427	
50	2008	Feather melanocytes	100MY	Vinther et al. The color of fossil feathers, Royal Society Biology Letters	rsbl.royalsocietypublishing.org/content/4/5/522				4(5):522-525	
49	2008	*Psittacosaurus* skin fibers	~125MY	Lingham-Soliar, *Psittacosaurus* complex fibre architecture, Proc Royal Soc B	ncbi.nlm.nih.gov/pmc/articles/PMC2596897/				275(1636):775-780	dino
48	2008	*T. rex* amino acid sequences	68MY	Schweitzer et al. Molecular methods examining..., Comptes Rendus Palevol	sciencedirect.com/science/article/pii/S163106	researchgate.net/publication/222219084_Microscopic_chemical_and_molecu			7(2-3):159-184	dino
47	2008	Osteocyte (bone cells)	5MY	Bell et al, Mineralized osteocyte: a living fossil, American Journal of Physics	ncbi.nlm.nih.gov/pubmed/18615594				137:449-456	
46	2007	*Tyrannosaurus rex* collagen	68MY	Schweitzer et al. *T. rex* soft tissue suggests the presence of protein, Science	sciencemag.org/content/316/5822/277.short				316(5822):277-280	dino
45	2007	*Triceratops* blood vessels, osteocytes	66MY	Schweitzer, Horner et al. Cellular preservation from Cretaceous, Proc RS B	rspb.royalsocietypublishing.org/content/274/16	See Table 1			274(1607):183-197	dino
44	2007	*T. rex* proteins sequenced	68MY	Asara, Schweitzer et al. Mastodon & *T. rex* protein sequences, Science	science.sciencemag.org/content/316/5822/28				316(5822):280-285	dino
43	2007	*T. rex* proteinaceous materials, sequenced collagen	40-150MY	Smejkal, Schweitzer, Will tech. enable dino proteomics, Exp Rev Proteomics	tandfonline.com/doi/full/10.1586/14789450.4.6				4(6):695-699	dino
42	2006	Frog bone marrow	10MY	McNamara et al. Organic preservation of amphibian bone marrow, Geology	geology.gsapubs.org/content/34/8/641?ijkey=c	In 2006 also, Schweitzer's Dangerous Discovery, dinosaurs smell like cadavers		discovermagazine.com/2006/apr/dinosaur-dna	34(8):641-644	
41	2005	Sauropod egg shell ovalbumin protein	~75MY	Schweitzer et al. Molecular preservation in dinosaur eggshells, P Roy Soc B	researchgate.net/publication/7853645_Molecu				272(1565):775-784	dino
40	2005	Avian bone collagen implying "molecular integrity"	~75MY	Avci, Schweitzer et al. Bone collagen from late Cretaceous, Langmuir	ncbi.nlm.nih.gov/pubmed/15807605	"No appreciable differences in collagen pull-off properties were measured between fossil and extant bone samples under physiological conditions."			21(8):3584-3590	
39	2005	Dinosaurian cellular and sub-cellular preservation	~68MY	Wittmeyer, Schweitzer, Dino vessels and cells in fossils, J Vert. Paleontology	jstor.org/stable/4524499?seq=1#page_scan_ta				25(3) 65th Ann. Mtg	dino
38	2005	*T. rex* vessels, cells, soft flexible connective tissue	68MY	Schweitzer, Horner et al. *T. rex* soft-tissue vessels, cellular preserv., Science	sciencemag.org/content/307/5717/1952.abstra				307(5717):1952-1955	dino
37	2004	Isolated non-spore-forming bacteria living in amber	120MY	Greenblatt et al. Micrococcus luteus - Survival in Amber, Microbial Ecology	digitalcommons.calpoly.edu/bio_fac/355/				48(1):120-127	
36	2003	Skin fibers	130MY	E. Frey et al., Palaeobiology of Pterosaurs, Geological Society Publication	catalog.princeton.edu/catalog/7809219				No. 217	
35	2003	Algal and bacterial organic molecules	**2.5GY**	Brocks et al. Biological diversity in molecular fossils, Geoch Cosmochem Acta	sciencedirect.com/science/article/pii/S001670				67(22):4321-4335	
34	2003	*Iguanodon* dinosaur osteocalcin protein	120MY	Embery et al. Iguanodon bone proteinaceous material, Connective Tissue R	tandfonline.com/doi/abs/10.1080/030082003	See the full paper at:	researchgate.net/publication/10586201_Identification_of_Prote		44(1):41-46	dino
33	2002	Metasequoia cellulose (with no O18)	34-56MY	Jahren, Sternberg, Oxygen isotopes in Arctic fossil wood, GSA Today	geosociety.org/gsatoday/archive/12/1/pdf/i105				1/2002:4-9	
32	2001	*Tyrannosaur rex* collagen SEM scans	65MY	Armitage, Mummified collagen fibers in fossil *T. rex* bone, CRS Quarterly	crsq.org/scanning-electron-microscope-study-r				38(2):61-66	dino
31	2000	Live bacteria from halite [salt] deposit	250MY	Vreeland et al. Isolation of halotolerant bacterium from salt crystal, Nature	nature.com/articles/35038060	Relevant protocol paper:	journals.plos.org/plosone/article?id=10.1371/journal.pone.0020		407:897-900	
30	2000	Non-collagen dinosaur proteinaceous extracts	125MY	Embery et al. Non-collagenous proteins from dinosaur *Iguanodon*, Conn Tis R	tandfonline.com/doi/abs/10.3109/030082000	"guanidinium chloride extractable protein [with the] levels of glycine, aspartate and serine tentatively suggest the presence of phosphoproteins."			41(3):249-259	dino
29	1999	*Alvarezsaurus* dinosaur β-keratin protein	~100MY	Schweitzer et al. Beta-keratin immunological reactivity, J Exper. Zoology	ncbi.nlm.nih.gov/pubmed/10440726				285(2):146-157	dino
28	1999	Similar live bacteria strains from separate rock salts	250MY	Stan-Lotter et al. Halococcus in Permo-Triassic salt deposits, Microbiology	mic.sgmjournals.org/content/145/12/3565				145:3565-3574	
27	1999	Keratin in Madagascar bird	65MY	Schweitzer et al. Immunoreactivity in Cretaceous bird, J. of Vert. Paleontology	tandfonline.com/doi/abs/10.1080/02724634.19				19(4):712-722	
26	1998	*Tarbosaurus* (*T. rex*) blood vessels	80MY	Pawlicki et al. Blood vessels and red blood cells in dinosaur, Annals Anatomy	ncbi.nlm.nih.gov/pubmed/9488909	Published in Germany (Anatomischer Anzeiger)			180(1):73-77	dino
25	1997	*T. rex* peptides and proteins; likely type 1 collagen	~68MY	Schweitzer et al. Biomolecules in Cancellous Bone, J. of Vert. Paleontology	jstor.org/stable/4523811?seq=1#page_scan_ta				17(2):349-359	dino
24	1997	Fossil diatom chitin	24MY	Stankiewicz et al. Preservation of chitin in 25-million-year-old fossils, Science	academia.edu/1557518/Preservation_of_chitin	See also:	science.sciencemag.org/content/276/5318/1473.11		276(5318):1541-1543	
23	1997	Heme in *Tyrannosaurus rex* bone	67MY	Schweitzer et al. Heme compounds in dinosaur trabecular bone, PNAS	pnas.org/content/94/12/6291.abstract				94(12):6291-6296	dino
22	1995	Live bacteria spores from a bee encased in amber	25-40MY	Cano and Borucki, Revival of bacterial spores in Dominican amber, Science	sciencemag.org/content/268/5213/1060.abstra	Cano didn't clone but "revived" this bacteria, in 1991	worldandischool.com/public/1996/january/school-resource1468		268(5213):1060-1064	
21	1994	Unaltered amino acids in amber insects	130MY	Bada et al. Insect in amber racemization, Geochemica Cosmochemica Acta	sciencedirect.com/science/article/pii/00167037				58(14):3131-3135	
20	1994	Cretaceous DNA for mitoochondrial cytochrome b	80MY	Wooodward et al. DNA sequence from Cretaceous bone fragments, Science	ncbi.nlm.nih.gov/pubmed/7973705	Related paper: Half-life of DNA is 521 years	rspb.royalsocietypublishing.org/content/early/2012/10/05/rspb.2	DNA should degrade to single bases in < 7M years	266(5188):1229-1232	dino
19	1993	Chloroplast tree gene partly sequenced (346 pairs)	35-40MY	Poinar et al. DNA from an extinct plant, Scientific Correspondence	nature.com/nature/journal/v363/n6431/abs/363	Dominican amber, extinct Hymenaea protera Poinar, 346-base-pair segment	Related paper: Half-life of papyrus DNA is 24 years	ncbi.nlm.nih.gov/pubmed/11920366	363(6431):677	
18	1993	Organic material in *T. rex* and theropod dinosaurs	65MY+	Ostrom et al. Trophic structure of Createaceous communities, Geology	geology.gsapubs.org/content/21/6/491.abstrac	In 1993 also: Dino DNA: The Hunt and the Hype	science.sciencemag.org/content/261/5118/160		21(6):491-494	dino
17	1992	Termite nuclear and mitochondrial DNA sequences	25-30MY	DeSalle et al. Oligo-miocene amber termite DNA sequences, Science	ncbi.nlm.nih.gov/pubmed/1411508	"mitochondrial [16S ribosomal DNA (rDNA)] and nuclear (18S rDNA) genes were amplified"			257(5078):1933-1936	
16	1992	Osteocalcin in a seismosaur dinosaur bone	150MY	Muyzer et al. Preservation of bone protein osteocalcin in dinosaurs, Geology	pubs.geoscienceworld.org/gsa/geology/article-				20:871-874	dino
15	1991	*Seismosaurus* [now, *Diplodocus*] vertebra proteins	150MY	Gurley et al. Proteins in bone of Seismosaurus, Journal of Protein Chemistry	ncbi.nlm.nih.gov/pubmed/2054066	smithsonianmag.com/science-nature/whatever-happened-to-seismosaurus-7	Smithsonian's dino guy Brian Switek has been a ST denier:	rsr.org/STDs	10(1):75-90	dino
14	1990	*Magnolia* leaf chloroplast 820-base DNA sequence	17-20MY	Golenberg et al. Chloroplast DNA sequence from Miocene *Magnolia*, Nature	nature.com/articles/344656a0	This paper has been challenged. Please send info/insights you may have on it to Bob@rsr.org. Thank you!			344(6267):656-658	
13	1990	*Tyrannosaurus* tooth hydroxyproline	~80MY	Ostrom et al. High molecular weight material, Adv. in Organic Geochemistry	sciencedirect.com/science/article/pii/01466380	Text available at:	s3.amazonaws.com/academia.edu.documents/40454295/Geoc		16(4-6):1139-1144	dino
12	1987	Seven hadrosaurs unfossilized bones	80MY	Davies, Duck-billed dinosaurs from the north slope of Alaska, J of Paleont.	jstor.org/stable/1305145?seq=1#page_scan_ta	"preservation is remarkable. The bones... display little permineralization..."			61(1):198-200	dino
11	1985	Metabolic pathways of dinosaur bones	80MY	Pawlicki, Metabolic pathways of dino bones Pt. 5, Folia Histochem Cytochem	ncbi.nlm.nih.gov/pubmed/4065383	Published in Poland (Folia Histochemica et Cytobiolgica)	See previous parts also, especially Parts 3 & 4.		23(3):165-174	dino
10	1976	Dinosaur gelatins made from fossil proteins	~100MY	Wyckoff et al. Pleistocene and dinosaur gelatins, Comp Biochem Physiology B	linkinghub.elsevier.com/retrieve/pii/030504917	Hydroxyproline, for example, indicative of collagen, was found in dino bones from Utah, Wyoming, Monatana, and Alberta, Canada.			55(1):95-97	dino
9	1976	Repeating sequence of mollusk shell glycoproteins	80MY	Weiner et al. Characterization of 80M-year-old mollusk shell proteins, PNAS	ncbi.nlm.nih.gov/pmc/articles/PMC430682/	"repeating amino acid sequence, found in contemporary mollusk shell proteins, was identified in the fossil glycoproteins."			73(8):2541-2545	
8	1974	Dinosaur proteins and polysaccharides	70MY	DeJong et al. Antigenic properties of macromolecules over 70 Myr, Nature	nature.com/nature/journal/v252/n5478/abs/252	"IT has been known for some time that many fossils still contain remnants of organic macromolecules, such as proteins and polysaccharides."			252(5478):63–64	dino
7	1972	Modern (advanced) proteins in many ancient fossils	~145MY	Schopf, Fossil Proteins "Biochemistry of animal fossils" book review, Science	science.sciencemag.org/content/178/4065/10	"the major conclusion is reached that 'analyses made of the oldest fossils thus far studied do not suggest that their proteins were chemically any simpler than those now being produced.'"			178(4065):1086	dino
6	1972	Jurassic collagen, evidence of various proteins	~145MY	Wyckoff, The Biochemistry of Animal Fossils, Scientechnica	books.google.com/books?id=f-YKAQAAIAAJ&	NAS member: "Jurassic bones have retained as much protein as the younger Cretaceous." p. 81		books.google.com/books?id=f-YKAQAAIAAJ&dq=-scho	152 pages	dino
5	1972	Biological material in saltwater clam shell	?	Crenshaw, M. A., Biomineralization Research Reports	books.google.com/books?id=DFTyAAAAMAAJ	Title: "The soluble matrix of *Mercenaria mercenaria* shell"		trove.nla.gov.au/work/11289249?versionId=13234046	6:6–11	
4	1968	Collagen from *Megalosaurus* dinosaur egg shell	166MY	Voss-Foucart, Paleoproteins, Comparative Biochemistry and Physiology	sciencedirect.com/science/article/pii/0010406X				24(1):31-32	dino
3	1968	Intact proteins from half of many bones	150MY	Miller, Wyckoff, Proteins in Dinosaur Bones, Proc. Nat'l Acad. of Sciences	jstor.org/stable/58447?read-now=1&loggedin=	"more or less intact proteins... can be recovered from... bones 150 MY old."		pnas.org/content/60/1/176.full.pdf	60(1):176-178	dino
2	1966	Collagen & vessels in dinosaur bone	200MY	Pawlicki et al. Cells, collagen fibrils and vessels in dinosaur bone, Nature	nature.com/nature/journal/v211/n5049/abs/211				211(5049):655-657	dino
1	1954	Devonian alanine, glutamic, & glycine amino acids	360MY	Abelson, Paleobiochemistry: Organic constituents of fossils, Carnegie Inst.	media.kgov.com/files/1954-carnegie-yearbook-	Amino acids for Devonian fish, Jurassic stegosaur, Cretaceous anatosaurus. Carnegie Institution of Washington full yearbook:		archive.org/details/yearbookcarne53195354carn	1954:97-101	dino
									Papers reporting *dinosaur* biomaterial:	58

*** Terminology**: In the age of sequencing extant endogenous dinosaur proteins, etc., the term "soft tissue" should be used with more care to clarify whether the claim is for merely permineralized, or still biological, remains. Perhaps the best general terms to refer to dinosaur and other organisms that have such endogenous biomaterial is "biofossil" and "biomaterial fossil". Hear this terminology discussed on the radio and see an example of the confusion caused by the ambiguity, over at rsr.org. Consider also that a significant number of, but not all, biofossil specimens have enough molecular preservation to be characterized as having still-soft "tissue". rsr.org/biomaterial-fossil-terminology

*** Papers Listed**: We consider for inclusion in the above list research papers that document biomaterial from sediments alleged to be at least five million years old (double the textbook age of the Quaternary). Gray cells mark the 50% of above papers documenting survival of *dinosaur* biomaterial. We use red font for the alleged ages of the 12% of the above papers with endogenous material claimed to be at least a quarter of a billion years old. (We also temporarily use red font for the numbers, column A, for papers newly added so that return visitors can see additions at a glance. Note, the paper numbers change when older papers are added.) Bold red "age", 5% of the above publications as of August 2021, marks biomaterial claimed to have survived at least a **half a billion years**.

*** Diagnostic Terms**: Is a publication referring to extant biomaterial or only to permineralization of such features as feathers, skin, scales, tissue, and organs? Authors use terms such as the following to refer to biomaterial: endogenous, endogeneity, molecular, cellular, sub-cellular, proteinaceous, protein fragments, sequence, beta-keratin, tubulin, actin, tropomyosin, myosin, hemoglobin, (etc.), heme, osteocytes, pigment, melanosomes, spectral signature, peptide, biomolecules, biomarkers, biochemistry, paleobiochemistry, nucleic acid, DNA, amino acids, chirality, still-soft, biomaterial, biofossil, transparent, immunology, immunological, immunofluorescence, antibodies, antigenic, antigenicity, collagenase, and unfossilized. See RSR. rsr.org/biofossils#diagnostic-terms

*** Bill Nye and Neil deGrasse Tyson**: Both men recently claimed that creationism makes no predictions. But see two RSR dinosaur soft tissue predictions, already confirmed, at rsr.org/predictions#soft, by allegedly 530 million-year-old Precambrian biomaterial, by sost tissue found in 6 of 8 dino bones, etc. rsr.org/predictions#soft

*** Corrections**: Please email suggested additions, corrections, fill-in-the-blanks (cell D115), or clarifications to Bob@rsr.org.

*** Apparently Discredited Claim**:

Year	Description	Age	Authors, Publication, etc.	Link	Notes
1993	Sequenced weevil DNA	130MY	Cano, et al, Amplification and sequencing of DNA, Nature	nature.com/nature/journal/v363/n6429/abs/363	Claimed as discredited, for example, in: phenomena.nationalgeographic.com/2015/06/16/scrappy-fossils-yield-possib

*** Contrary Papers** (We are waiting, patiently, for retractions of these papers by the authors or journal editors)

Paper	Link
2008 Dino soft tissue intrerpreted as bacterial biofilms, PLoS One Kaye et al.	plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0002808
2011 DNA Dinos Metagenomics, J Vert. Paleontology (abstract only) Salzberg	kgov.com/files/docs/Salzberg-2011-JVP-Dino-Metagenomics.pdf
2017 A fossil protein chimera... cross-contamination, Proc B Soc Buckley et al.	ncbi.nlm.nih.gov/pubmed/28566488
2020 Dino eggshell contains (racemized) amino acids, Usual suspects, preprint	biorxiv.org/content/10.1101/2020.06.02.129999v1

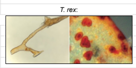
*** 30 Journals have published 58 original dinosaur biomaterial reports** (as of August 2021, half of the above papers), so this is no isolated phenomenon.

1. *Acta Histochemica* (Italy)
2. Advances in Organic Chemistry
3. Annals of Anatomy (Germany)
4. Comparative Biochemistry and Physiology
5. *Comptes Rendus Palevol* (France)
6. Connective Tissue Research
7. Cretaceous Research
8. Creation Research Society Quarterly
9. Current Biology
10. Expert Review of Proteomics
11. Folia Histochem Cytobiol (Poland)
12. Geology
13. Journal of Experimental Zoology
14. Journal of Paleontology
15. Journal of Protein Chemistry
16. Journal of Proteome Research
17. Journal of Vertebrate Paleontology
18. Microscopy Today <- journal most recently added to the list
19. National Science Review

Here's what's been discovered in dinos, etc:

In fossils from dinosaur-layer and "deeper", i.e. believed older, strata, researchers have discovered flexible and transparent blood vessels and cartilage, red blood cells, starch, many various proteins including beta-keratin, the microtubule building block tubulin, collagen, mollusk shell glycoprotein and dino eggshell peptides and chelating ligands, chitin, the cytoskeleton components actin, tropomyosin, and the related motor protein myosin, and hemoglobin, bone maintenance osteocyte cells, pigment including melanosomes, clearly-seen chromosome-like structures within cell nucleus, DNA-related histone proteins, and powerful evidence for DNA including positive results from multiple double-helix tests including IP and DAPI on fossils from various dinosaurs.

T. rex:



Dinosaur and dinosaur-layer creatures:

The dinosaurs and other Mesozoic creatures that have yielded their biological material include multiple species of hadrosaur, titanosaur, [ostrich-like] ornithomimosaur, *Nodosaur*, mosasaur, [bird-like] *Anchiornis huxleyi*, *Triceratops*, *Lufengosaur*, *Archaeopteryx*, and *T. rex*.

Dinosaur tissue reports are rare in the popular meda:

youtu.be/0-I See a rare example in the mainstream media in 3-min clip on ABC's 60 Minutes

List of Biomaterial Fossil Papers (maintained)

20	Nature			
21	Nature Communications	**Dinosaur biomaterial is becoming expected in the scientific literature**		
22	Nature Scientific Reports	periodicos.s	Brazil's Portuguese language journal Terrae Didatica, 6/20 "[R]egarding the frequency of soft tissue findings... The prediction is that acquisition of new technologies will turn such findings as the norm and not the exception."	
23	Paleontology			
24	PeerJ			
25	PLoS ONE			
26	Proc Royal Society B		We agree with Didatica but note that the use of existing technologies already makes such findings routine. New technologies, including those reducing the time and cost for such investigation, and those enabling molecular identification even while still in the field, will certainly increase the frequency of biofossil discoveries. (The latter, enabling in situ analysis, will of course introduce additional challenges.)	
27	Proc. of the Nat'l Acad. of Sciences			
28	Science			
29	Science of Nature (Germany)			
30	Swiss Journal of Geosciences			

Google Scholar 2020 (search terms & resulting numbers of papers):		scholar.google.com
"exceptional preservation" fossil	6,570	scholar.google.com/scholar?hl=en&as_sdt=0%2C6&q=%22exceptional+preserva
"exceptionally well preserved" dinosaur	1,780	scholar.google.com/scholar?hl=en&as_sdt=0%2C6&q=%22exceptionally+well+pr
"remarkable preservation" fossil	1,510	scholar.google.com/scholar?hl=en&as_sdt=0%2C6&q=%22remarkable+preserva
"remarkably preserved" fossil	919	scholar.google.com/scholar?hl=en&as_sdt=0%2C6&q=%22remarkably+preserve
"remarkably preserved" microfossils	187	scholar.google.com/scholar?hl=en&as_sdt=0%2C6&q=%22remarkably+preserve

* **Candidates**: If you investigate any of these papers or have others to recommend, please send your thoughts to Bob@rsr.org. Thanks!		
2020 Phylogenetic and physiological signals in... biomolecules, Weimann, et al.		advances.sciencemag.org/content/6/28/eaba6883
2020 Dino eggshell has (racemized) amino acids, Saitta, Vinther, Kaye, et al.		biorxiv.org/content/10.1101/2020.06.02.129999v1
2020 Autofluorescence of Dinosaur Bone Reveals Encapsulation of Blood Clots		cambridge.org/core/journals/microscopy-today/article/uv-autofluorescence-microsc
2019 Early Cretaceous bird preserving unlaid egg and probable medullary bone		nature.com/articles/s41467-019-09259-x
2019 Smithsonian report of NMNH's allegedly 14Mya still wood conifer Pinophyta		smithsonianmag.com/smithsonian-institution/how-do-fossils-form-1-180972340/
2017 Organic Matter in Fossils, Encyc of Geochemistry, Muscente, Czaja, et al.		link.springer.com/referenceworkentry/10.1007%2F978-3-319-39193-9_185-1
2017 Exceptionally preserved fossil assemblages Gondwana Res Muscente et al		sciencedirect.com/science/article/abs/pii/S1342937X17302107?via%3Dihub
2016 Protein sequences bound to mineral surfaces persist into deep time		elifesciences.org/articles/17092
2013 DNA preservation dissertation 34mya possible biomarkers Penn St. Richter		etda.libraries.psu.edu/catalog/21122
2005 Ancient DNA comes of age, PLoS Biology		ncbi.nlm.nih.gov/pubmed/15719062
2004 Occurrence of ink in Paleozoic and Mesozoic coleoids (Cephadopoda)		researchgate.net/publication/28645546_Occurrence_of_ink_in_Paleozoic_and_
2003 Chem Evidence for Lignification and Tracheids in Early Devonian Plants		journals.uchicago.edu/doi/abs/10.1086/377113
1998 Color banding in feathers of two dinosaurs from China, Nature		nature.com/articles/31635
1996 Chemical characterization of Lower Devonian vascular plants		sciencedirect.com/science/article/pii/S0146638096001404
1956 On the colour of an icthyosaur (possible presence of melanocytes)		tandfonline.com/doi/abs/10.1080/00222935608655889
* **Candidates in Amber** and the amber itself for that matter		rsr.org/article/scan-amber-trapped-spider-shows-recent
2011 Proteins from amber, Sample Preparation in Biological Mass Spectrometry		link.springer.com/chapter/10.1007/978-94-007-0828-0_45
Former Candidate papers not promoted are listed at Row 50 of...		docs.google.com/spreadsheets/d/1JiNcTdtMoPfhNXum6FZ6TQ_F6F4NZgXPM

* **Preliminary Reports**: The scores of papers published since the year 2000 suggest that the scores of early papers published from 1954 to 1999 deserve more credibility than they were typically given.				
11/15/17	Amino acids in Antarctica fossil forest	280MY	Live Science	livescience.com/60944-ancient-fossil-forest-dis
9/27/10	Lobster shell	"millions"	Keighley News	keighleynews.co.uk/news/8405907.Fossil_find
8/10/09	Live yeast in amber	45MY	Wired Science	wired.com/science/discoveries/magazine/17-0
4/13/07	charcoal in limestone cave preserves cellular details	310MY	ScienceDaily and University of Illinois at Chicago	sciencedaily.com/releases/2007/04/070412102
'93-'17	Original dinosaur biological material	65-150MY	Science, J Vert Pal, Proc R Soc, PLoS One, PNAS, Nature, Nat. Comm., etc.	DinosaurSoftTissue.com#research

See RSR's Other Lists:		
List of List Shows		rsr.org/lists
List of Living Fossils		docs.google.com/document/d/1kDBEuNJxwbKDBV-54fLRkLmZs8SyJ1k0mYFD
List of Not So Old Things		rsr.org/list
List of Genomes that Just Don't Fit		rsr.org/genomes
List of Ways Water Stops Abiogenesis (NASA answers RSR)		rsr.org/abiogenesis
List of Problems with Eye Evolution		rsr.org/eyes
List of Problems with Whale Evolution		rsr.org/whales
List of Problems with "The River Carved the Canyon"		rsr.org/not-the-river
List of Problems with the Grand Canyon's Millions of Years		rsr.org/gc6
See ICR's original 2011 soft-tissue list that grew into the above, at:		docs.google.com/spreadsheets/d/1JiNcTdtMoPfhNXum6FZ6TQ_F6F4NZgXPM
(On row 50 of the same sheet see the discussion with an old-earth geophysicist.)		Dec 2018 - Feb 2019
And see Brian Taylor's 2019 "Toast" article at:		rsr.org/article/11137
Want to save time? Use RSR's custom Google science search at:		rsr.org

Find this at:	DOI: 10.13140/RG.2.2.10126.61766	bflist.rsr.org	researchgate.net/publication/324484996_Biomaterial_Fossils_List_to_2019_at_b