Evidence

Model Credit: Tyler Keillor, photograph by Ximena Erickson, from http://blog.everythingdinosaur.co.uk/blog

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Learning objectives

• Think like a macroevolutionary biologist/paleontologist and reconstruct a community

• Learn how biologists gather evidence for macroevolutionary processes
Break into groups of two.

What do your “fossils” tell you?

What species live there [and not just the plants]?

What’s the climate like?

What else can you glean from them?

(wash hands after class)
• Molecular fossil
• Trace fossil
• Body fossil
• Phylogenetics
• Extant organisms
• Experiments
It was recently stressed that thermocatalytic reactions yield homologous series of organic compounds with no carbon number preferences (Rushdi and Simoneit, 2001) and that Fischer–Tropsch-type products are dominated by unbranched alkanes with a characteristic linear decrease in abundance (McCollo and Seewald, 2006). In contrast, a weak odd-over-even carbon number predominance is a unique characteristics of organics formed biologically since it reflects biosynthesis using addition of C2 units (Albro, 1976). The C_{10}-C_{18} range in the alkanes of the Warrawoona pyrolysate is characterized by such odd-over-even carbon number predominance (Fig. 3b), confirming the involvement of a biosynthetic pathway in the formation of these n-alkyl chains (a carbon preference index value of 1.2 is calculated in this range (Bray and Evans, 1961)). As a result, Fig. 3b provides evidence for the presence of molecular markers of life in this Warrawoona sample.

The biological origin of organic matter in the oldest siliceous sediments (cherts) is still debated. To address this issue, the insoluble organic matter (kerogen) was isolated from a chert of the Warrawoona group. The chemical structure of the kerogen was investigated through a combination of analytical techniques including solid-state $^{13}$C nuclear magnetic resonance and pyrolysis. Although dominated by aromatic hydrocarbons, the pyrolysate comprises a homologous series of long chain aliphatic hydrocarbons characterized by odd-over-even carbon number predominance. This distribution is only consistent with a biological origin. As kerogen must be contemporaneous of the solidification of the chert, this observation should be regarded as an evidence for the presence of life on Earth, 3.5 By ago.
Biogeochemical and stable carbon isotopic analysis of black-shale sequences deposited during an Albian oceanic anoxic event (~112 million years ago) indicate that up to 80 weight percent of sedimentary organic carbon is derived from marine, nonthermophilic archaebae. The carbon-13 content of archaean molecular fossils indicates that these archaebae were living chemoautotrophically. Their massive expansion may have been a response to the strong stratification of the ocean during this anoxic event. Indeed, the sedimentary record of archaean membrane lipids suggests that this anoxic event marks a time in Earth history at which certain hyperthermophilic archaebae adapted to low-temperature environments.
JENSEN. Predation by early Cambrian trilobites on infaunal worms-evidence from the Swedish Mickwitzia Sandstone. Lethaia (1990)
The Paleocene–Eocene Thermal Maximum (PETM, 55.8 Ma), an abrupt global warming event linked to a transient increase in $p$CO$_2$, was comparable in rate and magnitude to modern anthropogenic climate change. Here we use plant fossils from the Bighorn Basin of Wyoming to document the combined effects of temperature and $p$CO$_2$ on insect herbivory. We examined 5,062 fossil leaves from five sites positioned before, during, and after the PETM (59–55.2 Ma). The amount and diversity of insect damage on angiosperm leaves, as well as the relative abundance of specialized damage, correlate with rising and falling temperature. All reach distinct maxima during the PETM, and every PETM plant species is extensively damaged and colonized by specialized herbivores. Our study suggests that increased insect herbivory is likely to be a net long-term effect of anthropogenic $p$CO$_2$ increase and warming temperatures.

Fig. 1. Representative insect damage diversity on PETM leaves. (a) Dicot sp. WW007 (Fabaceae) leaf about one-third consumed by insect herbivores (USNM 530967). (b) Characteristic large, circular hole-feeding (DT4) found only on dicot sp. WW006 (530968). (c) Serpentine mine with a solid frass trail becoming massive (DT43) on an unidentifiable dicot (530969). (d) Polylobate to clustered galls (DT125) on dicot sp. WW007 (Fabaceae, 530970). (e) Blotch mine with a sinusoidal frass trail (DT37) on dicot sp. WW003 (530971). (f) Blotch mine with distinct coprolites and terminal chamber (DT35) on dicot sp. WW006 (530972). (g) Serpentine mine with a solid frass trail (DT43) on dicot sp. WW004 (530973). (h) Semilinear serpentine mine with terminal chamber (DT40) on dicot sp. WW005 (530974). (Scale bars: white, 1 mm; black, 5 mm.)
Fig. 3. Systematic affinities of fossil phytolith morphotypes (Supporting Online Text) reported from Maastrichtian coprolites from Psidura, central India, suggesting significantly older dates for taxonomic diversification within the grass family (Poaceae) than previously assumed (1–3). The phylogeny is from the Grass Phylogeny Working Group (1). Approximate ages for the crown node of Poaceae and for immediate sister taxa (marked with a gray circle) were provided by molecular clock analysis (5). White shapes indicate open-habitat grass clades; black shapes and all other terminal taxa indicate closed-habitat grasses. Fossil phytolith morphotypes are as follows: CD, Chitalaya decena; EL, Elasemundel lamelii; JP, Jaimin psiduresis; MI, Matleytes indicus; PP, Piperno psessua; SI, Stebbinsiana intertrans; TS, Thomasonites sinuatus; VP, Vorhuenite papillares. 

Figure 2. Bedding-plane *Leanchoilia* with phosphatized midgut glands showing bilateral organization. A, ROM 54214; heavily phosphatized midgut with conspicuous biserial nodes. B, ROM 54211; lightly phosphatized midgut with pronounced sagittal and segmental divisions, resulting in biserial patches of phosphate.
By combining evidence from descriptive anatomical work, physical modelling, mathematical approaches and new technologies, palaeontologists are able to gain a more comprehensive knowledge of dinosaur feeding behaviour, which, in turn, improves our understanding of Mesozoic ecology. Here, we demonstrate how this approach can be used to investigate the palaeobiology of *Tyrannosaurus rex*, whose gargantuan size and specialized anatomy have made it a favourite of functional morphologists.

Comparisons of the craniodental morphology of *T. rex* (Figure la) to living animals indicate that this animal was a carnivore. Wear facets on the teeth show that tyrannosaurids practiced repeated shearing between upper and lower dentitions [44] (Figure lb), offering a processing mechanism for flesh and bone. Puncture-like bite marks on a *Triceratops* pelvis [15] (Figure lc) and extensive damage to the tail of one specimen of the duck-billed dinosaur *Edmontosaurus* [62] demonstrate the ability of *T. rex* to penetrate bone. Two types of repetitive biting behaviour are observed: deep puncture of thinner cortical bone and, in deeper cortical bone, shallow puncture followed by pulling of the teeth across the bone surface [15]. Comparison of the cutting ability of fossilised teeth to that of varied replica blades demonstrated that stout tyrannosaurid teeth (Figure ld) functioned as pegs with poor cutting ability. Instead, the teeth were used to ‘grip-and-rip’ prey – the ‘puncture-pull’ feeding hypothesis [17,18]. Space-frame analysis suggests that the *T. rex* skull was constructed to resist strong, vertically directed bite forces [25]. FEA provides information on stress-strain patterns within the skull, and confirms that the *T. rex* cranium could withstand large feeding-induced puncture-pull loads [34] (Figure le). Furthermore, FEA studies suggest that tyrannosaurid nasal bones were fused and thickened to withstand large compressive and shear stresses, and that open skull sutures assisted in ‘shock-absorption’ during powerful bites [34].

Replica teeth driven into bovine bone (mimicking the morphology of the bitten *Triceratops* pelvis) indicate that *T. rex* could produce bite forces exceeding 6410 Newtons [16], well in excess of those estimated for modern lions, showing that a *T. rex* bite could shatter bone [16]. This hypothesis is confirmed by the discovery of a *T. rex* coprolite [65] (Figure lf) that contains large quantities of pulverized bone pertaining to an ornithischian dinosaur. In this instance, the bone of the prey animal was only partially digested, indicating that gut-residence time was short [65]. Finally, although most palaeontologists agree that *T. rex* was an active predator at least some of the time [49,50], recent ecological energetic analysis of the *T. rex*-bearing Hell Creek Formation suggests that, providing competition for carrion was low, it could have survived purely as a scavenger [29].
H5N1 bird flu: phylogeography & evolution

Wallace et al, 2007
Ryan & Rand, 1995
Weir & Schluter, 2007
Stickleback species pair from Paxton Lake, British Columbia. Gravid benthic top, gravid limnetic bottom.

Photo by Todd Hatfield, taken from http://www.zoology.ubc.ca/~schluter/stickleback/stickleback_species_pairs/Stickleback_Species_Pairs.htm
**Fig. 1.** The experimental design used in the study of group selection. The curves indicated prior to “Selection” represent smoothed histograms of the census data gathered for each treatment with numbers of adults on the abscissa and numbers of populations on the ordinate.
Think of macroevolutionary questions. Which source(s) of evidence would you use to address these?

- Molecular fossil
- Trace fossil
- Body fossil
- Phylogenetics
- Extant organisms
- Experiments