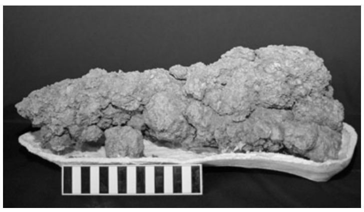
Fossil preservation processes



Tyrannosaurus turd, Eastend Saskatchewan

Information loss in the fossil record

After an organism dies, its tissues are commonly subjected to destructive processes.

The average person can see these processes in action ! Take a close look at roadkill next summer !

Scavenging organisms, eat soft tissues, removing, or scattering the remaining material.

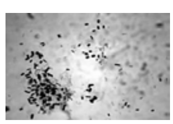
Large scavengers
Eat up boys !

Small scavengers
(e.g. insect larvae)
Yum !

Bacteria are important in breaking down dead organic matter at the molecular level.

Physical weathering mechanically breaks down hard, mineralized tissues (e.g. shells, bone, teeth)

Mineralized tissues also tend to dissolve (via chemical weathering), and erode, if exposed at the surface.



Corpse bacteria

Physical and chemical
Weathering, and erosion

BUT…as a general rule, hardparts have a greater chance of survival in the fossil record than do soft tissues.

This is because hardparts are more robust, more stable (in a chemical sense) and are less prone to destruction via decay.

Major effects of pre-burial processes are:

Soft Tissue Decay: Destruction of soft parts (e.g. muscle, skin, nerve tissue)- this also occurs in soft tissues (e.g. blood vessels) within hardparts such as bone.

Disarticulation: Dissociation of hard parts

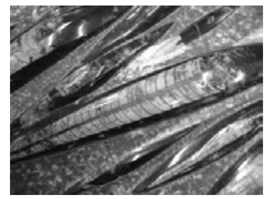
Fragmentation: Breakage and dissociation of fragments thus formed

Dissolution: Breakdown of hardparts via dissolution of minerals in hardparts.

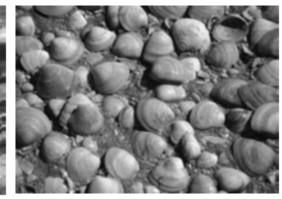
Abrasion: Erosion of hard tissues due to “sandblasting” effects of suspended sediment particles

Note: Some of these processes affect others
For example, decay of organic components of hardparts as well as dissolution can weaken hardparts, rendering them more prone to fragmentation and abrasion.

In some cases, the orientations of fossil remains can indicate aspects of the environment in which they were deposited.



Current-aligned shells of the nautiloid Orthoceras (indicates unidirectional current)



Convex-up bivalve shells with bidirectional orientation of umbos (bidirectional currents related to wave action)

Factors That Favour Fossilization

Special conditions are therefore required to preserve dead tissues (most organisms have < 5 % chance of leaving any trace of their existence in the fossil record).

Two of the most important factors that promote the preservation of remains are:

1. Rapid burial/entombment – This isolates remains from the work of scavengers and long-term physical disturbance.
2. Low oxygen – This also allows remains to be isolated from scavengers (most of which need oxygen to survive) and slows down bacterial decay. The precipitation of certain minerals that enhance preservation also tends to occur in oxygen-free environments.

In many cases, rapid burial and low-oxygen conditions go hand-in-hand.

Common Mineral Compositions Of Hard Parts

calcium carbonate $CaCO_3$
aragonite – unstable (tends to be dissolved)
calcite – stable (tends to be well-preserved)
Principal mineral components of most seashells

silica SiO_2 – stable (tends to be well-preserved)
Principal mineral component of skeletal component of some sponges, and a few micro-organisms such as diatoms and radiolaria.

calcium phosphate (apatite)
$Ca_3(F.Cl.OH)(PO_4)_3$ –stable (tends to be well-preserved)
Principal mineral component of bones, teeth and some shells

Post-Burial Processes:
Modes of Preservation

Unaltered/Actual Remains

Skeletal remains that are composed of stable minerals (e.g. calcite or silica) can be preserved without significant change in chemical makeup or internal structure.

Hardparts (mineralized skeletal components such as shells, teeth and bones) are more likely to be preserved close to their original state because they are less prone to breakdown. However, under rare circumstances, soft tissues can also be preserved without significant alteration.

Unaltered/ Actual Remains

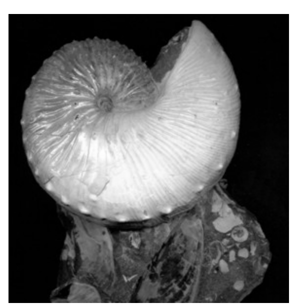
Hardpart Preservation

These brachiopod shells are made of calcite. This is the same calcite that was present in the shells when the animals died.

Even though these shells are about 375 million years old, they have undergone minimal change in their chemical and physical attributes.

Unaltered/ Actual Remains

Hardpart Preservation



Although less stable than calcite, aragonite (the other mineral form of calcium carbonate) is occasionally preserved.

This ammonite (the shell of a squid-like mollusc) preserves its original nacreous layer (mother of pearl), composed of sheets of aragonite crystals.

More on nacre a little later in the course !

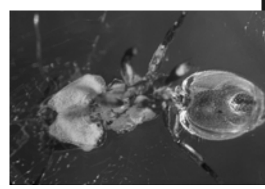
Unaltered/Actual Remains

Soft Tissue Preservation: Refrigeration

Mammoth preserving original hair and flesh

Unaltered/Actual Remains

Soft Tissue Preservation: Amber Entombment



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scorpion

Unaltered/Actual Remains

Soft Tissue Preservation: Tar Impregnation

“pickled” beetle

Altered Remains

More often than not, fossil remains are physically and/or chemically altered in some way.

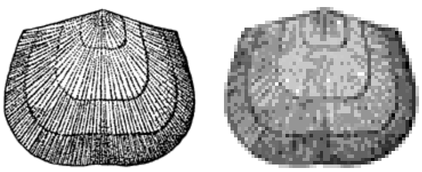
Four main types of alteration processes are

1. Recrystallization
2. Petrifaction/Permineralization
3. Replacement
4. Carbonization

Recrystallization

Although some hardparts can be preserved with little change, most experience at least some degree of recrystallization after burial (crystals tend to increase in size due to the higher temperatures encountered below Earth's surface)

Over time, crystals of a given mineral tend
to increase in size (to achieve greater stability)



Increase size of crystals
Loss of detail

Petrifaction/Permineralization

Occurs when mineral matter fills small pores of the remains of an organism

Petrified wood

Petrified dinosaur bone

Replacement

In some cases, organic matter or minerals of an organism can be *replaced* by different mineral substances. This replacement occurs at a microscopic level.

Depending on the chemistry of porewaters within sediment, a number of minerals can replace the original material.

Calcite shells are commonly replaced by silica (silicon dioxide), pyrite (iron sulphide) or apatite (calcium phosphate).

Replacement: Silicification
(replacement by silica)

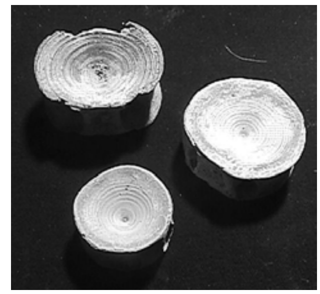
fossil sponge
(originally calcite)

Brachiopod
(originally calcite)

Replacement: Pyritization
(replacement by pyrite)

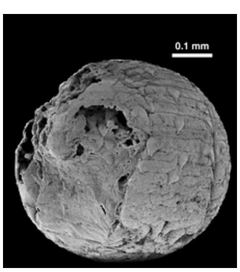
pyritized brachiopod (originally calcite) calcite-shelled brachiopod

Replacement: Phosphatization
(replacement by apatite)



shark vertebrae
(originally cartilage)

Replacement: Phosphatization
(replacement by apatite)



Replacement is not restricted to hardparts.

In rare instances, soft tissues can be replaced by minerals (thereby enhancing their preservation)

Phosphatized embryo of arthropod (crustacean ?) in egg

Carbonization

Carbonized fern leaves and coal

Carbon-rich remains such as plant matter is lightly heated when buried.

During this low-grade cooking, elements such as oxygen are released, while carbon is left behind.

As a result, the remains are enriched in carbon.

Coal is basically fossilized organic sludge that accumulates in swamps.

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Moulds and Casts

Moulds

When remains are buried, they are surrounded with sediment.
The impression of the buried object made in the surrounding sediment is called an *external mould*.

If the buried object is hollow, it can also be infilled with sediment. The impression of the interior of the buried object is called an *internal mould*.

In many cases, the actual buried object (in this case a shell) decays or is dissolved, leaving only internal and external moulds.

Internal mould   External mould

Note: the original shell of this ammonite has completely dissolved away, but its former presence is indicated by external and internal moulds.

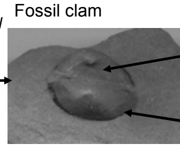
Moulds

Clam

1. Sediment surrounding the shell and filling the shell cavity hardens

2.Shell is dissolved

Fossil clam



Internal mould

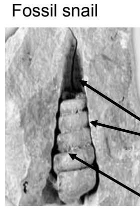
External mould

Snail

1. Sediment surrounding the shell and filling the shell cavity hardens

2.Shell is dissolved

Fossil snail



Fossil snail

External mould

Internal mould

Casts

Casts are formed when an external mould is infilled by sediment or precipitated minerals. It appears as a replica of the original buried object.

In this case, the sediment surrounding a tree trunk hardened sufficiently to hold its shape after the tree trunk completely decayed.

Sediment was later washed into the resulting hole (an external mould), producing a natural cast.

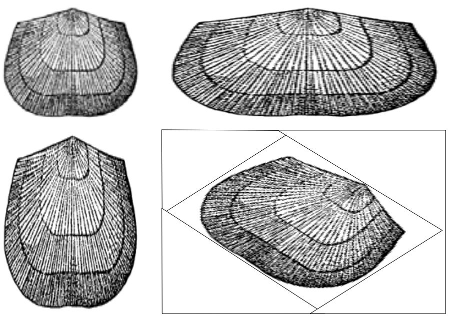
In this case, the cast is made entirely of sandstone (none of the original tissue has been preserved).

Cast of Tree Trunk

Post-burial processes

Effects of compaction:

Fossil shape can become distorted due to differential pressure (associated with tectonic activity)



Body Fossils vs. Trace Fossils

Thus far, we have concentrated on the remains of organisms. As these fossilized remains represent body tissue, we call them *body fossils*.

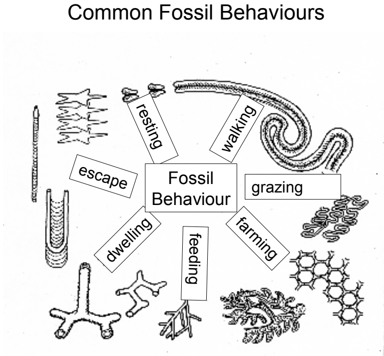
But body fossils aren't the only types of fossils that we have to work with.

We also find *trace fossils*.

Trace fossils record the *activities* of ancient organisms.

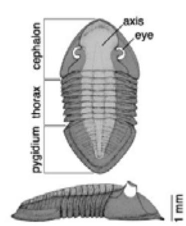
Whereas body fossils tell us things about the *anatomy* of organisms, trace fossils provide evidence of *behaviour*.

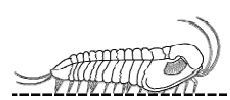
Common Fossil Behaviours



Identification of Trace Fossils

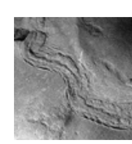
Note: a single organism may produce multiple types of traces (e.g. trilobites produce resting, ploughing (feeding), and walking traces, all of which look very different)





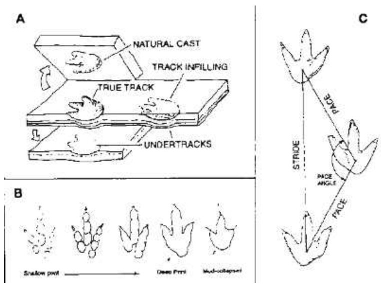
resting

walking

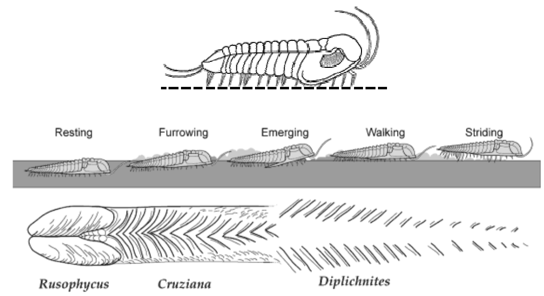


ploughing

Footprint morphology



Behaviour patterns



Stromatolites

trace fossil formation by
sediment accretion
- sediment trapping by
bacterial slime mats

Modern stromatolites

Ancient stromatolites

Coprolites: Fossil excrement

Dinosaur coprolite

Fish coprolites

END OF LECTURE