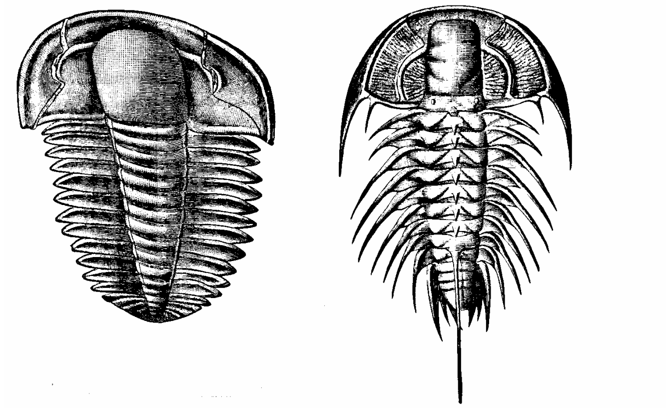

Week Five

Origins and Preservation of Life (Fossils)

Background: For the rest of the semester, you will get up-front and personal with various **fossils** from the **geologic** or **rock record.** The study of fossils is called **paleontology**. Most people (and that includes GY 112 students), have a rudimentary understanding of fossils and paleontology, but there are also a lot of misconceptions that need to be corrected. You will eventually come to appreciate that animals evolved at different geological times, and a lot of the juxtapositioning that we envision is incorrect. For example, primates are recent additions on this planet. Consequently, there is no way that humans (e.g., Fred Flintstone) could have lived with the dinosaurs. Hollywood commonly confuses geological time and the evolution of life. The 2000 animated Disney film *Dinosaur* featured cute fuzzy lemurs attempting to save an orphaned baby dinosaur 65 million years ago. Unfortunately, there was a time gap of many 10s of millions of years between the death of the dinosaurs and the evolution of those primates.

Another misconception is the difference between paleontology (*the study of fossils*) and **archaeology** (*the study of the remains of man*). **Paleoanthropologists** study fossil man but they do not study dinosaurs. If an archeologist happened to find the skull of a *Tyrannosaurus rex* in a site that was supposed to contain hominid remains, then he or she either dug too deep, or read the map incorrectly.

Earth's biological history can be revealed through studying the evidence of past life. Indeed as you have seen in class, the fossil record greatly contributes to theories in other components of Geology as well as to Biology. Paleontology is a subdiscipline of Geology that studies ancient forms of life, their interactions as well as evolution. Paleontology can be broken down into many specific areas including **paleobotany**

Two species of trilobite, just one of many thousands of beasties that have come and gone in the geological record. Figure from Le Conte, J., 1905. Elements of Geology. D. Appleton & Co. New York, 667p.

(*the study of fossil plants*), **micropaleontology** (*the study of microscopic fossils*), **invertebrate** and **vertebrate paleontology** (*the studies of, respectively, fossils without, and with, backbones*).

The term *fossil* refers to anything that is recognized as direct evidence of, or an indication of, pre-existing life. Fossils include both the remains of animals and plants (**Body fossils**), and the traces of those organisms (e.g., burrows, plant roots, feces; **Trace fossils**). It is a sad fact that most of the organisms that lived in the past left no record of their existence. perhaps more than 90% of all the life on this planet was never preserved in the rock record. Fossil preservation is rare and depends upon many conditions. To become preserved in the geologic record, an organism must:

- have preservable parts such as bones, shells, teeth, or wood.
- must have lived in a suitable environment for fossilization

One other thing should be stated about fossils before we get to the next section. Some of the fossils that you will see in the lab here and in the rocks out "there" are the remains of extinct "beasties". Trilobites died off at the Permian-Triassic boundary 245 million years ago so any rocks you find that contain trilobites must be at least 245 million years old. But not all of the fossils that you will encounter represent extinct groups. Some even have living relatives. For example, there is a mollusc shell (a bivalve) in New Zealand called *Austrovenus stutchburyi* that today only lives in estuaries and very shallow marine environments around that country. Students that went on a USA trip to that country in 2001 found fossils of *Austrovenus stutchburyi* in rocks 500,000 years old on top of a mountain 1000 feet high that was 25 km away from the shoreline. This indicates 2 things: 1) the shell, which is *not* extinct, has been around for at least half a million years (quite a long time for a bivalve) and 2) 500,000 years ago, the top of the mountain had to have been at sea level. Paleontology can provide an enormous amount of important information if you are a careful and accurate observer.

Terminology: As a general rule, text books and lab manuals that have long lists of scientific terms are boring and quite often unreadable. However, every once in a while, authors have no choice but to present a lot of terms in a hurry. This week's lab is just such a case. The following are important concepts that you will need to know for this and the remaining labs in GY 112.

Taphonomy is the study of what happens to an organism after its death and until its discovery as a fossil. Prior to discovery, fossils may experience decomposition, post-mortem transport, burial, compaction, and other chemical, biologic, and/or physical activity which affect the remains. Some paleontologists break this down into three stages: necrology, biostratinomy, and diagenesis.

1. **Necrology** is the first stage of the process which involves the death of the organism or loss of a body part. This is not like losing an ear (e.g., Vincent van Gogh). Crabs shed or molt their shells seasonally and this

can become part of the geologic record.
2. Processes that occur between the death of an organism and its subsequent burial in the sediment are termed **biostratinomy**. Generally, this includes decomposition and scavenging of the animal's soft parts and at least some amount of transport.
3. The physical and/or chemical effects after burial are called **diagenesis**. This can include alteration of sediment induced by chemical interactions, and changes in pressure and temperature.

Where a fossil begins the process of becoming part of the geologic record can have implications on the paleoenvironment. Many different processes affect how well a fossil is preserved or even if it survives to be preserved. For example:

Abrasion: Wearing-down of parts due to movement with respect to sediment is an indicator of environmental energy. Significant abrasion is commonly found on skeletal material collected from areas of high energy such as beaches, areas of strong currents or wave action. In some cases, body parts are completely obliterated.

Articulation: Skeletons are usually **disarticulated** or broken up soon after death. Articulated skeletons, therefore, indicate rapid burial or otherwise removal of the skeleton from the effects of energy of the original environment.

Bioerosion: This encompasses many different corrosive processes by organisms. For example common causes of degradation are **boring** and **grazing** (trace fossils on fossils!)

Dissolution: Changes in chemical conditions after death and burial can cause skeletons to dissolve (**partially** or **completely**). Rates of dissolution are affected by fluctuations in temperature, pH or changes in calcium carbonate content. Siliceous skeletons can also dissolve because normal sea water is usually undersaturated with respect to silica, but the most common mineral showing signs of dissolution is **aragonite** (see discussion on the next page).

Encrustation: The growth of hard skeleton substrates by other organisms is a common occurrence. Besides indicating exposure of the skeleton above the sediment-water interface, encrustation can specify a particular environment. Different patterns of encrustation, as well as different biota, occur in different environments.

Fragmentation: Breakage of skeletons is usually an indication of high energy resulting from wave action or current energy. Fragmentation also can be caused by other organisms through either predation or scavenging.

Orientation: After death, skeletal remains are moved by the transporting medium and oriented relative to their hydrodynamic properties. Articulated fossil skeletons indicate rapid burial, attachment to a firm substrate, or death in place (*in situ*). Hard parts tend to orient with the dominant **paleocurrent** and can be perpendicular to the longitudinal direction of a wave.

So, a fossil can take on many forms. Various modes of preservation are found in the geologic record. The modes are dependent upon the conditions of preservation at the time of and well after death. Here are some examples of what can be found and what you may see in your lab assignment.

Modes of Preservation: As discussed in class, fossils can be preserved through different processes. This section details the most common modes of preservation.

Unaltered (Pristine) Preservation: This occurs when the original material is preserved within the rock record. Overall, it is not a common occurrence. Unaltered body parts may include hard components (shells, tests, skeletons) or soft components (tissue, cellulose etc). Unaltered hard parts are highly variable in terms of mineral composition. Here is a summary of the most common "biogenic" minerals and some of the major fossil groups that use them to construct hard body parts.

1) Calcium Carbonate ($CaCO_3$), occurs in three forms that are employed by animals to build hard body parts. **Aragonite** is a very common mineral, but not very stable in the presence of **meteoric water** (i.e., "fresh water"). As a result, most aragonitic fossils that have been exposed for even short periods of time to fresh water lose their **pristine** appearance and appear **"chalky"**. This is because the fossils have been **partially dissolved**.

Aragonite is widely used by modern molluscs (includes clams and snails) and corals and lots of other beasties, but it is rare in rocks older than the Cretaceous. **Calcite** is a more stable polymorph of calcium carbonate (at least in meteoric water) and is used by many types of molluscs, brachiopods, bryozoans, foraminifera, trilobites and some extinct groups of corals. The third carbonate mineral is usually called **high magnesium calcite** (or just **magnesium calcite**). It is a type of calcite where Mg^{2+} makes up more than 4% of the mineral (typically 12 to 18%) and is given the formula: $Ca(Mg)CO_3$. Magnesium calcite is used by several types of calcareous algae and echinoderms

2) **Calcium Phosphate**. Several varieties of this compound occur as minerals (including apatite). This is the major mineral constituent of vertebrate bones.

3) **Opal** ($SiO_2 \cdot H_2O$). Is relatively soluble in water (at least compared to quartz or chert) and so it rarely survives unaltered. It is used by some marine microfossils (e.g., diatoms and radiolarians), and is sometimes found in algae and sponges.

4) **Chitin**. This is a major component of arthropod exoskeletons - like crabs and insects. It is an organic compound that is similar to cellulose. Chitin is often subject

to biotic decay so sometimes all that is left is a carbonized film. Trilobite exoskeletons were made of this and other materials.

5) **Combinations** - Many hard parts are made of a combination of mineralogies. For example, trilobites often have exoskeletons made of chitin impregnated with high magnesium calcite. Some bryozoans are composed of aragonite and calcite.

Soft body parts are very rarely preserved, but are among the most eagerly sought fossils. Here, original soft parts as well as hard parts are preserved. Things were protected from the destructive processes that are described above. Examples of the these rare finds include:

Freezing	Mammoths in ice
Petroleum	Saber Tooth Tigers in the La Brea tar pits
Dehydration	Animal (and human) mummified remains
Impression	outlines of worms and leaves in fine grained rocks like shale

Entombment: This occurs when animals become encased in an agent that cuts them off from potentially destructive processes (e.g., oxidation). Soft and hard parts are usually preserved. The most common material involved in entombment is **amber** (fossilized tree sap). Insects are frequently preserved in this manner.

Replacement (mineralization): In this type of preservation there is an actual substitution of one mineral for another. The detail of preservation varies from excellent to crappy depending upon the speed and manner of replacement. Almost all types of mineral replacement are induced by pore water within the rocks that contain the fossils. As the water seeps through the rock, it may dissolve some components of the fossil, but simultaneously precipitate another mineral in its place. If the dissolution-precipitation process occurs at a small scale (e.g., one molecule at a time), replacement can be done without losing too much of the original detail. Often this replacement occurs at the cellular level, preserving many microscopic details of the original specimen. If the replacement is less selective, you will get a poorly preserved fossil. You may see many types of replacement. Here are some of the most common varieties. You may want to refer to your mineral notes from the first week's lab to tell the how to distinguish between the various minerals:

- Replacement by Calcite
- Replacement by Dolomite
- Replacement by Silica (Silicification)
- Replacement by Pyrite (Pyritization)
- Replacement by Hematite
- Replacement by Limonite

Permineralization: Many original materials are porous, like bones, wood and shells. These pore spaces can be filled in by other minerals which is called perimineralization. It is NOT mineral replacement as you can't "replace" a hole with a mineral. You must FILL IT IN.o. Cryptocrystalline quartz (chert) and silica are common perimineralization minerals. Unaltered bone will look spongy, be soft (hence easily scratched), and be lighter than altered bone which will be heavier with the 'holes' filled in. The same goes for wood materials that when altered will be dense and harder to scratch. Even certain corals and sponges can be permineralized.

Petrifaction: This is the replacement of organic material AND the filling in of holes by secondary minerals. Petrifaction therefore consists of mireal replacement *and* perimineralization. Chert is the most common pertification substance. Test for it using the standard hardness tests.

Recrystallization: This is close to, but not exactly the same as, mineral replacement. Here, the chemical composition of the fossil remains the same, but the original crystals have changed in form or size. For example, larger crystals of calcite may overprint the original smaller crystals. Often you may actually see individual mineral crystals as part of the body of the fossil. Many of the fine details of the specimen are lost and the shape often distorted.

Carbonization: In this type of preservation, as decomposition occurred, the specimen lost all of its oxygen, hydrogen, and nitrogen leaving mostly carbon behind. The remains are generally a black or grey film. Plants are often preserved in this manner but graptolites, fish, and arthropods can also be found in this state. Plant material in this form can be referred to as a **carbon impression**.

Concretions: This mode of preservation involves a fossil found inside a concretion or nodular rock. As the sediment encapsulated the specimen, the minerals cemented to the soft tissues. Commonly calcite or siderite ($FeCO_3$) is the preserving material. Concretions may part along a plane of weakness that was created by the presence of the fossil (e.g., parallel to a leaf or fish).

Molds: This is an impression of the original specimen in the enclosing sediment. The mold can be **external** or **internal**. A mold actually makes an 'opposite' image of fossil. So, where there may be ridges and knobs on the actual specimen, in a mold they will look like indentations and depressions. When you walk on the beach your foot leaves a mold behind. If you pour plaster into the mold you get a cast of the bottom of your foot ….. which leads to…….

Casts: This type of preservation occurs when minerals or sediment fill the void where the original material once was. The mineral or other material will take its form from the mold, so the cast is a replica of the original, now long gone. For most specimens found prior to the Phanerozoic Eon, soft parts had to leave molds (impressions) in soft sedimentary materials in order to preserve their existence.

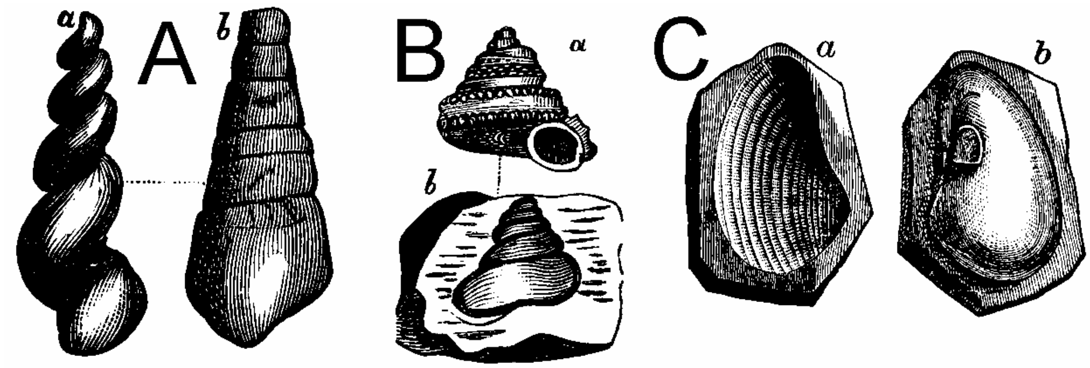

Figure 5-1: *Images of casts and mold. A: A turritelid gastropod; a - the internal mold; b - the external unaltered portion of the test. B: Another gastropod; a the unaltered test; a cast of the test. C: A bivalve shell; a - an external mold of the shell; b - an internal mold of the shell. Figure from Le Conte, J., 1905. Elements of Geology. D. Appleton & Co. New York, 667p.*

Miscellaneous fossils (and fossil preservation): Not all fossil remains are actually remains of body parts. Some are less appealing. For example, **coprolites** are fossilized feces. The major form of preservation in this material is replacement so don't worry about picking up the specimens. **Gastroliths** are reputed to be "fossilized" dinosaur gizzard stones. A skeptical find, these generally non-descript rocks are about fist size and have an interesting gloss to them which paleontologist attribute to stomach acid.

Pseudofossils: Just when you thought you knew it all about fossils comes things that are NOT fossils. **Dendrites** look like small plants branching on the side of rocks but they are actually mineral encrustations such as manganese oxide. **Slickensides** are vertical striations along rock faces that are the result of movement along a fault face.

Trace fossils (also called **ichnofossils**) are the evidence of a plant or animal's activity. Although not true fossils (they are not the remains of body parts), trace fossils preserve evidence of organism's activities/behaviors. They include footprints, vertical burrows, horizontal feeding traces, resting marks and scavenging furrows. Ultimately, they record disturbances from activity such as locomotion, feeding, or rooting. They are very useful in the interpretation of paleoenvironments. Given that trace fossils reflect activity, many different organisms doing the same thing can produce similar traces. Likewise, an organism engaged in a different activity can leave more than one trace. These types of remnants in the geologic record are the cause of **bioturbation** which is defined as the disturbance of sediments due to biologic activity.

The morphology of trace fossils can be described with respect to their position relative to their original depositional surface. A few activity traces are:

Locomotive Traces: Are usually straight or slightly curved trails in addition to tracks and trackways.

Resting and Hiding Traces: Are characterized by the fillings of shallow excavations that mimic the morphology of the trace maker.

Dwelling Traces: Include burrows, borings, or other excavations where the beasties lived. They can be vertical unbranched cylinders or U-shaped.

Feeding Traces: Includes the burrows of sediment feeders usually with a distinct three-dimensional shape. They may be dendritic, multibranched or take on other patterns.

Grazing Traces: Include grazing burrows that are two-dimensional features which occur along bedding surfaces as a spiral, S-shaped series of curves, or other patterns. Grazing organisms are efficient feeders. Rarely do grazing burrows cross one another.

Paleoecology and Ichnofacies: An **ichnofacies** is a recurring assemblage of one or more ichnofossils which are characteristic of a particular environment. Trace fossils within a given inchnofacies often have similar morphologies which is presumably due to a similar activity of the fossil organisms which made them. A couple of examples include:

Scoyenia Ichnofacies: These are non-marine trace fossils that mainly include foot prints, trails, and trackways which were originally made in moist sediments.

Skolithos Ichnofacies: Occurs in soft or firm sediment (but not lithified) within the intertidal or shallow subtidal zone.

Cruziana Ichnofacies: The Cruziana ichnofacies are characterized by simple locomotion traces with some U-shaped dwelling and shallow resting and hiding traces. The Cruziana ichnofacies is common in middle to outer shelf clastic settings.

Had more than you ever wanted to know? Now your work begins. You may supplement your work by googling fossil preservation on the internet..

Name: ________________________ **Grade** ____/100 (+5 bonus) Percent: _____

GY 112 Lab Assignment 5

Modes Of Preservation

Note: In this lab we will begin to look at fossilized animals, plants, and their traces. You will soon become very familiar with the various beasties that occur in sedimentary rocks, but you have to start somewhere and this will be your first good introduction to fossils. The first part of the lab will involve a lecture/show-and-tell session. These samples will give you examples of some of the styles of preservation that we discussed in the lecture(s).

Part A: Show-and-tell specimens.

During the lab lecture, you will be shown a variety of fossils and fossil preservation. These specimens will **not** be left in the lab. After the demonstration, if you wish, look at the specimens and make a few notes to help you remember the various types of preservation. You don't get any points for this section, but it is good data to help you study for upcoming lab tests. **[0 points]**

Part B: Fossil preservation

The following specimens will be found in the labeled drawer in room LSCB 335. They are labeled with purple numbers, and most are in boxes. Take care in handling the specimens as some belong to various members of the department and can be expensive to replace (translation: if you break our personal specimens you will be *killed*). Please be careful not to mix up the specimens and their corresponding boxes. This leads to confusion and your carelessness is unfair to the other students.

Sample 5-1: This is a rather nicely preserved specimen of *Pectin*, a bivalve collected from Pensacola by a Marine Sciences Ph.D student. It is here to provide inspiration for your first writing question: In the space below, briefly discuss some of the criteria that can increase the chance of fossil preservation (refer to the web lecture on fossil preservation for help in answering this question).

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____ **[3 points]**

Sample 5-2:

This specimen is another species of bivalve. What is its mode(s) of preservation?

____ **[2 points]**

Sample 5-3:

This specimen has both leaf and fern imprints in it. What is the name of the rock that contains it?

____**[2 points]**

What is the mode of preservation of the plant fossils?

____**[2 points]**

What do the plant fossils tell you about the paleoenvironment of deposition of the

rock? ____

____**[3 points]**

Specimen 5-4:
This rock is a fossiliferous limestone that is composed of nothing but shell fragments. What is another sedimentary name for the rock?

____ **[2 points]**

Notice that the rock contains some oysters and serpulid worm tubes (see sample 5-24 for comparisons). What term do we use to describe their modes of attachment?

____ **[2 points]**

Specimen 5-5:
Box 5-5 contains two types of gastropod (snails). What are their mode(s) of preservation?

____ **[2 points]**

Question 5-6 (no specimens):
Describe how recrystallization works.

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____ **[3 points]**

Specimen 5-7:
The specimen in box 5-7 is a brachiopod shell. Why is it "gold"-colored?

____**[2 points]**

What is the mode(s) of preservation of the brachipod?

____ **[2 points]**

Specimen 5-8:

What is the dominant form(s) of fossil preservation in rock 5-8?

____ **[2 points]**

Specimen 5-9:

What general type of fossil is contained within specimen 5-9? (choose from trace or body fossil)

____ **[2 points]**

What can you say about the feeding preference of the beastie that left the fossil behind in specimen 5-9 (e.g., did it burrow or crawl or swim or float to eat)?

____ **[2 points]**

Specimen 5-10:
The specimens in box 5-10 are remnants of a gastropod and a bivalve shell. Do we see the inside or outside of the fossils?

____________________________________ **[2 points]**

Specimen 5-11:
What material is this specimen composed of?

____**[2 points]**

What organisms or body parts are normally fossilized in this material?

____**[2 points]**

Specimen 5-12:
This box contains a bivalve shell and a piece of colonial coral. How would you describe their appearance? (Hint; How hard are they? What color are they?).

____**[2 points]**

Given your answer above, what mineral are the beasties composed of?

____**[2 points]**

Specimen 5-13:
This specimen contains leaf imprints. In what object are they preserved?

____**[2 points]**

Specimen 5-14:
What general type(s) of fossils are in specimen 14? (choose from trace or body fossil)

____**[2 points]**

What is the specific name of these fossils?

____**[2 points]**

What is the name of the rock that they are preserved in?

____**[2 points]**

Specimen 5-15:
What general type of fossil is specimen 5-15? (choose from trace or body fossil)

____**[2 points]**

What is the name of the rock that contains the fossil?

_______________________________________ **[2 points]**

Specimen 5-16:
This specimen is a piece of petrified wood. What mode(s) of preservation have occurred?

____ **[2 points]**

What geological material is responsible for these mode(s) of preservation?

___________________________ **[1 point]**

Specimen 5-17:
This specimen is a biochemical sedimentary rock that contains bryozoans and brachipods, beasties that used calcite to construct their body parts.(Ask for help in identifying these beasties). What is the rock name?

____ **[2 points]**

What are the mode(s) of preservation of the fossils?

____ **[2 points]**

Specimen 5-18:
This specimen is yet another biochemical sedimentary rock with bivalve shells in it. What is the rock name?

____ **[2 points]**

What is the mode(s) of preservation of the shells?

____ **[2 points]**

Specimen 5-19:
The rocks comprising this specimen retain evidence of several types of fossils. What are the mode(s) of preservation of the fossils?

____ **[2 points]**

Specimens 5-20a and 5-20b:
These two specimens are pieces of bone. One is an original porpoise vertebrae (5-20a) and the other is an isolated bone fragment (5-20b). What is the mode of preservation of specimen number 5-20a?

____ **[2 points]**

What is the mode of preservation of specimen number 5-20b?

____ **[2 points]**

What characteristics tell you specimen 5- 20b has been fossilized in this mode?

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____

____ **[3 points]**

Specimen 5-21:
Specimen 5-21 is a large ammonite. What is its mode(s) of preservation?

____ **[2 points]**

Specimen 5-22:
This specimen contains the remains of an old "friend". Well, not literally, but you have seen bits and pieces of these beasties before. They are called crinoids and were stalked animals that lived attached to the sea floor.

What is the mode(s) of preservation of the crinoids?

____ **[2 points]**

Explain how this form of preservation occurred.

____

____

____ **[3 points]**

Specimen 5-23:
This specimen is a biochemical sedimentary rock that contains bivalve shells and turritella gastropods. What is the rock name?

____ **[2 points]**

What is the mode(s) of preservation of the fossils?

____ **[2 points]**

Specimen 5-24:
These are the fossilized tubes of calcite precipitating worms called serpulids. The worms secreted the tubes for protection from predators as they grew. They are not body parts, so how what kind of fossils must they be?

____ **[2 points]**

Specimen 5-25:
This is the fossilized remains of a colonial coral. What do you call the mode(s) of preservation?

__________________________________**[2 points]**

What mineral is responsible for this instance of fossilization?

__________________________________**[2 points]**

Question 5-26 (no specimens):

What can tracks tell you about an animal?

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____ **[5 points]**

Name: ______________________________

Question 5-27 (no specimens):
What can tracks tell you about paleoenvironment?

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____ **[5 points]**

Bonus Questions: On your way home tonight (or to class tomorrow), stop by the lobby of the Life Sciences Building that leads to the outside Lecture Hall and check out the decorative stone that the builders (clever lads that they were) choose to line the walls with. What kind of rock is it?

_________________________________**[2 points]**

Do you see any fossils in the stone? If so, what are they and how are they preserved? (there may be more than one type of fossil or one type preservation).

____

____**[3 points]**