Lab 7: Echinoderms

Name:

Section:

AIMS:

This lab will introduce you to echinoderms, a very diverse deuterostome phylum with an excellent fossil record. You will see examples of several echinoderm classes, but the lab focuses on the three most commonly found as fossils: echinoids, crinoids, and blastoids. You will also conduct an analysis investigating how the range of morphology ("disparity") of blastoids changed through time. By the end of this lab, you should be able to recognize the commonest classes of echinoderms and understand how their morphology reflects their mode of life, and have an appreciation for how morphometrics can be used to address questions of morphospace occupation.

INTRODUCTION

The Echinodermata is a diverse deuterostome phylum with several unique attributes: pentameral (five-rayed) symmetry, a skeleton of many mesodermal porous calcitic plates (stereom ossicles), and a water vascular system by which the locomotory tube feet or filtering podia are extended. The earliest representatives were stalked filter-feeders, and echinoderms therefore lack a true head. All are marine, and discovery of a fossil echinoderm is a sure sign that the entombing sediment was deposited in a normal marine environment. The earliest unambiguous echinoderms are found in Lower Cambrian strata, and the phylum has a good fossil record throughout the Phanerozoic.

Echinoderms fall within two major groups: the unstalked eleutherozoans (including the Echinozoa, the Asterozoa, and the extinct Homalozoa), and the stalked pelmatozoans (including the Crinozoa and the extinct Blastozoa). Although the phylum is represented by six classes today, its maximal diversity in terms of number of classes was in the Paleozoic: some 24 classes are known, most from the Ordovician. This lab focuses

on the three classes (Echinoidea, Crinoidea, and Blastoidea) which are most abundant in the fossil record.

PART A: ECHINOIDS.

Echinoids (sea urchins) are vagrant, benthic, non-stalked (eleutherozoan) echinoderms with <u>no free arms</u>: the ambulacra are confined to the body (which is typically globose or discoidal in form). The ossicles of an echinoid skeleton are firmly fused together, making the test rigid. Echinoids first evolved in the Ordovician, and remain important members of marine ecosystems today. The early echinoids all show pentameral symmetry: such <u>regular echinoids</u> are still abundant today. However, echinoids underwent a major diversification in the Mesozoic with the evolution of <u>irregular urchins</u> with secondary bilateral symmetry superimposed upon the ancestral pentameral pattern.

A1:   Recent regular echinoids.

These specimens exemplify the basic morphology of the regular echinoid test, with (A1a) and without (A1b, c) the spines.

<u>DRAW</u> the test of a regular echinoid without its spines (A1b or A1c). Note the pentameral symmetry, ambulacra, interambulacra, pore pairs, genital plates, ocular plates, madreporite, periproct, spine bases, and the space previously covered by the peristome.

List all the features visible on the test which are associated with the water vascular system.

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What is the function of the pore pairs?

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What is the function of the madreporite?

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What mode of life is a regular echinoid adapted to?

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A2:   "Teeth" of a regular echinoid.

CAREFULLY examine these "jaws" of a modern regular echinoid: each apparatus is very fragile. The apparatus consists of 40 calcitic plates, with five large "teeth". Specimen A2a retains the peristome through which the "teeth" project.

What name do we give to this "tooth apparatus"?

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A3:   Spines from a regular echinoid.

What functions were the spines used for?

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How did they attach to the test?

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A4:   Fossil regular echinoids.

Examine these fossil regular urchins, which include cidaroids from the Mesozoic (A4a) and a Carboniferous perischoechinoid (A4b).

How do perischoechinoids differ from cidaroids?

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A5:   Recent irregular echinoid.

DRAW the test of this irregular sea urchin. Note the bilateral symmetry superimposed on the basic pentameral symmetry, the ambulacra, interambulacra, pore pairs, genital plates, madreporite, periproct, spine bases, and peristome.

What mode of life are irregular echinoids adapted to?

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What is the function of the tube feet associated with the "petaloid" portion of the ambulacra on the aboral surface of irregular echinoids?

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What evolutionary changes (relative to regular echinoids) have occurred in the test in association with the switch to this mode of life?

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A6:   Fossil spatangoid echinoids.

These irregular echinoids show an anterior groove in the test (weakly developed in A6a and A6b, more strongly developed in A6c).

What is the function of the anterior groove?

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Micraster, a Cretaceous spatangoid, has been intensively studied in terms of its morphological evolution (see Clarkson, 1998, pp. 282-284).

A7:   Sand dollars.

Sand dollars are irregular echinoids with a highly flattened test. They are the most recent major group of echinoids to have evolved, first appearing as fossils in the Paleocene. Examine the tests of these Recent and fossil sand dollars, ensuring that you can identify the typical echinoid features.

How do the spines of sand dollars (A7a, b) differ from those of a regular echinoid?

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Where does the mouth of these sand dollars lie?

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Where does the periproct lie?

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How are the fossil sand dollars preserved?

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A8: Sand dollars with lunules.

Lunules are the large perforations (holes) in the test

What is the functional purpose of lunules?

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PART B: CRINOIDS.

Crinoids are stalked echinoderms (pelmatozoans) which, at first glance, vaguely resemble plants (indeed, they are often referred to as "sea-lilies"). The typical crinoid body consists of a small calyx of many small plates, attached to the seafloor by a long stem and a root-like holdfast. Crinoids are well adapted to a filter-feeding mode of life, with an upward-facing mouth and a series of arms which sprout from the calyx to form a filtration fan. The five ambulacra run along the pinnule-lined arms, which can bifurcate to give a greater filtering surface. Podia, equivalent to the tube feet of echinoids, extend from the pinnules and are used in filtering particles out from water currents passing through the arms. Crinoids are extant, but were far more abundant and diverse in the Paleozoic, particularly during the Carboniferous Period when their remains sometimes formed vast sheets of crinoidal limestones ("encrinites": B7c, d).

B1:   Articulated fossil crinoid.

Note the basic anatomy of this well-preserved fossil crinoid. The stem is composed of numerous stacked ossicles called columnals, each resembling a "Lifesaver" mint (with a hole in the center through which soft tissue passed). The arms are not preserved: the large projections from the calyx are spines.

B2:   *Cactocrinus* (Carboniferous).

The calyx and arms of this fossil are remarkably complete, even down to the multitude of pinnules. Note the ornament of raised radiating ridges on each plate of the calyx.

B3:   *Actinocrinus* (Carboniferous).

The arms of this crinoid were broken off prior to fossilization. However, the arm bases are still preserved on the calyx. Note that each of the five primary arms bifurcated upon sprouting from the calyx: the initial bifurcation is evident in this fossil. The calyx plates of this species were ornamented with raised ridges and tubercles or spines.

B4:   Crinoid calyx.

The arrangement of plates on the calyx is very useful for identifying crinoids. Various types of plates are recognized according to their position on the calyx or the arm bases (infrabasals, basals, radials, brachials, and interbrachials), although not all crinoids possessed all of these plate types. See Clarkson (1998, pp. 293-296) for details.

Was this crinoid monocyclic or dicyclic?

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B5:   *Eucalyptocrinus* calyx.

With reference to figure 9.38 in Clarkson (1998), DRAW and label an "exploded calyx diagram" for this crinoid, showing the number and arrangement of plates on the calyx.

Was this crinoid monocyclic or dicyclic?

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B6: *Platyceras* gastropod on a *Gilbertsocrinus* calyx.

This fine specimen preserves an ecological relationship between taxa from the Carboniferous period. See also specimen A6 (Lab 6).

How could you potentially determine whether the relationship was parasitic or commensal? What kind(s) of data would be needed?

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B7: Crinoid columnals.

The stem of crinoids served a very important function in feeding, holding the calyx in position to maximize filtering efficiency. Rheophobic crinoids feed using a horizontal filtration bowl, catching the steady rain of food particles settling vertically out of the water column. This requires a relatively inflexible stem. Rheophilic crinoids feed using a vertical filtration fan, catching food particles caught in laterally directed water currents. This requires a highly flexible stem, able to bend in response to shifting water currents. The flexibility of the stem was determined by the style of articulation between adjoining columnals (see figure 9.44 in Clarkson, 1998): a synostosial articulation (plane surface) pattern gave minimal stem flexibility, while synarthrial articulation allowed adjoining columnals to rock (like a "see-saw") across the raised fulcral ridge, giving highly flexible stems. Symplexial columnals, with corrugated radial ridges, permitted some flexibility without twisting.

What kind of articulation is developed on the isolated columnals (B7a)?

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What are the circular scars on the pleuricolumnal stem portions (B7b)? What is their functional significance?

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B8: Crinoid holdfast.

Crinoids evolved many kinds of holdfast, which enabled the group to radiate into many environments. Holdfast morphology is functionally linked with substrate type and the mode of attachment of the crinoid.

What kind of substrate do you think this root-like holdfast was adapted for? Why?

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B9: Stemless crinoids.

The vast majority of Recent crinoids shed their stems during development, and are motile as adults (walking or swimming with their long, highly flexible arms). They grip to surfaces with modified cirri which sprout from the base of the calyx. The stemless morphology is well demonstrated by comatulid crinoids, which first arose in the Jurassic and which comprise about 90 of the 115 extant crinoid genera. *Antedon* (B9a) is a modern comatulid.

What might have been a major selective pressure in the switch in dominance from stalked to non-stalked morphologies in shallow-water settings during the Mesozoic?

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Saccocoma (B9b) is the most abundant macrofossil known from the Upper Jurassic Solnhofen Limestone of Germany, a deposit most famous for preservation of the early bird *Archaeopteryx*. *Saccocoma* was apparently a pelagic comatulid crinoid.

What attributes of *Saccocoma* (in terms of its morphology and its preservation) suggest that this was a pelagic animal?

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Uintacrinus (B9c) is a stemless crinoid which occurs in spectacular clusters on bedding surfaces of Upper Cretaceous deposits such as the Niobrara Formation (see the slab mounted in the entryway of this building). It is the largest stemless crinoid, and there is considerable debate as to its mode of life.

Examine the slab and the literature on *Uintacrinus*. Discuss the support for and against this animal having a pelagic mode of life.

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PART C: BLASTOIDS.

Blastoids were the most abundant class of the extinct blastozoan echinoderms, although there were many other blastozoan classes. Like crinoids, blastoids were stalked pelmatozoan echinoderms with a plated calyx (or tegmen) atop a stalk of columnals. However, blastoids lacked free arms: the podia for filter-feeding emerged from numerous brachioles which sprouted directly from the ambulacra on the calyx. Blastoids also possessed a very complex respiratory system. Blastoids evolved in the Ordovician and became extinct during the Permian.

C1:   *Pentremites* (Carboniferous).

Pentremites is a common blastoid and shows all the typical features of the group. DRAW the calyx. Note the spiracles, ambulacra and interambulacra, the site of stem attachment, and the various plates of the calyx (basals, radials, and deltoid plates).

Where was the mouth of a blastoid?

How does the calyx of a blastoid differ from that of a crinoid?

<u>C2: Thin-section through a *Pentremites* calyx.</u>

This thin-section cuts through the calyx of a *Pentremites* individual, and shows details of the complex respiratory structures which characterize blastoids.

<u>DRAW</u> the thin-section, and label the parts you can see. Use Clarkson (1998, fig. 9.47) to help you.

What were the functions of the various features you can see?

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PART D: BLASTOID DISPARITY THROUGH TIME.

In this exercise, you will collect basic morphometric data on a small sample of blastoid echinoderms in order to see how morphometrics (literally, the quantification of shape) can be used to distinguish morphotypes (i.e., groups of specimens sharing similar shapes, clustering together in morphospace). You will then analyze a dataset of previously collected blastoid measurements in order to assess how the range of morphology expressed by blastoids (i.e., blastoid disparity) changed through the Paleozoic.

It is assumed that you have already read the accompanying readings (see the file "Geos224Lab7Readings" on the web page) as background to morphometrics and disparity. These readings are drawn from a textbook manuscript (*Principles of Paleontology,* Third Edition, by M. Foote and A. I. Miller, with contributions by D. M. Raup and S. M. Stanley) and a technical paper on blastoids (*University of Michigan Museum of Paleontology*, vol. **28**, no. 6, pp. 101-140 [1991]).

1. Using Morphometrics To Distinguish Morphotypes.

Use the calipers to measure the blastoid specimens provided. For each specimen, measure (1) the maximal oral-aboral "height", and (2) the maximal width perpendicular to this. From these measurements, compute the height:width ratio (also known as the vault:pelvis ratio for blastoids) for each specimen.

Plot the position of each specimen on a univariate graph in which the x-axis is the vault:pelvis ratio.

How many distinct morphotypes (species) do you think are represented by these specimens? Explain your answer.

2. Blastoid Disparity Through Time.

The foregoing procedure can ideally be used to establish whether a collection of specimens is likely to represent one or more species. In addition to the number of species (also known as *richness* or *taxonomic diversity*) it is often important to know how dissimilar the species are from each other. This is the question of morphological diversity or *disparity.* You will now use a spreadsheet program to calculate a temporal sequence of disparity values for blastoids.

Make a personal copy of the file "Geos224Lab7Data.xls" on the lab computer. Double click on your copy to open the spreadsheet. Each row represents a single specimen. The columns consist of a code number for the specimen, the genus name, the species name, and the geologic age, followed by a series of morphometric measurements. The specimens are grouped by geologic age (ORD2: Middle & Upper Ordovician; SILU: Silurian; DEV1: Early Devonian; DEV2: Middle & Upper Devonian; LCAR: Lower Carboniferous; UCAR: Upper Carboniferous; PERM: Permian). The measurements are transformed x-, y-, and z-coordinates for eight landmarks on the blastoid theca, as explained in the accompanying readings. (Because some of the landmarks are used to constrain the orientation of the specimen, there are only 17 rather than 24 measurements.) The measurements were taken with a special microscope that allows digital recording of landmark coordinates in three dimensions. The column headed "x2" refers to the x-coordinate of landmark number 2, etc.

We will use the variance to express the dispersion of data for each variable, and we will use the sum of the variances over the variables as a measure of disparity. Since there is only one specimen for the Ordovician, disparity is undefined. For the Silurian sample, the following calculations have already been performed:

STEP 1: Click on the cell below the list of values for x2, which is cell E11 in the spreadsheet. Type in the following expression exactly:

$$=VAR(E5:E10)$$

…and press <return>. This will cause the variance of the values in cells E5 through E10 to be computed and written to cell E11.

STEP 2: Click on cell E11 and then choose "Copy" from the Edit menu at the top of the page. This will copy the formula into the computer's buffer.

STEP 3: Now use the cursor to highlight cells F11 through U11. Choose "Paste" from the Edit menu. This will cause the formula from cell E11 to be copied to cells F11 through U11, and in each case the necessary adjustments will be automatically made (so that F11 contains the variance for cells F5 through F10 etc.).

STEP 4: In cell V11, type in the following formula:

<div align="center">

=SUM(E11:U11)

</div>

…and press <return>. This will cause the sum of the variances you have calculated to be written to cell V11. This sum of variances is your estimate of morphological disparity for the Silurian blastoids.

STEP 5: Now repeat this procedure for each of the time intervals.

Plot a graph depicting disparity through time for blastoids.

In light of your background reading of disparity, discuss the significance of your results.

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Your disparity calculations in some cases involved more than one specimen of the same species. How might your results have differed if you had used just a single specimen per species or had represented each species by its mean values?

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If you are feeling ambitious, make another copy of the spreadsheet and explore these alternative protocols.