Notes taken by Sandra Romano, at the EOL BioSync meeting.

Final agenda for the coral workshop/EOL synthesis meeting, June 15-19, 2009

[June 10, 2009]

Monday June 15

Focus for the day: Introductions and primers

Monday AM (Waldo Schmitt Room, W218-B):

8-8:30am: Participants should plan to arrive at the NMNH by this time. Monday presenters should arrive at 8:15 with a thumb drive, preferably for PC (but Mac can be accommodated). The password for the wireless in the Schmitt room is: x$piyto5U. The meeting room is cold so be sure to bring a sweater or a jacket.

9:00-9:15am: Welcome to the Smithsonian [Cairns, Sues]

9:15-10:45am: Introductions, including Corallosphere, Treatise on Invertebrate Paleontology, EOL [Budd, EOL staff]; all participants should be prepared to give a 2-minute synopsis of who they are and the topic of their research (and/or what their role is in the project)

Cindy Parr EOL: director of spp pages; based at NMNH; 5 different components distributed across US; purpose of EOL to bring together info about all organisms known to science; funded by MacArthur and Sloan Foundations; build technical infrastructure first; will have rigorous curatorial network;

Ken Johnson Corallosphere: online database to make info immediately available as the Treatise is revised

Stolarski Treatise on Invert Paleontology: Being revised

Alistair Spaezel? Historian of coral science; post-doc;

10:45-11am: COFFEE BREAK

11-11:15am: Meeting goals and approach [Budd]

Long-term goal: To develop a phylogeny and classification sysem for the Scleractinia, which integrate morphologic and genetic data and include the fossil record

Come up with a plan to create a tree like Wells 1956

Short term goals

- Corallosphere: glossary of morphological terms; consistent approach to morphologic diagnoses; instructions for authors; prioritize the work; generic diagnoses
- Treatise Vol 1 and 2: commitments from authors and determine timetable; construct phylogeny/classification system and integrate Corallosphere glossary; discuss transfer of data from Corallosphere
- Encyclopedia of Life: Develop a plan for sharing data

11:15am-12pm: Primer on molecular results, target audience= morphologists [Knowlton]

Talk for the paleontologists
Recent molecular results Fukami et al 2008
50-75 morphological characters- this many available in a single gene- possibility of 100s of molecular characters and in many cases they are independent
Well studied model of evolution
Problems with genetic methods

- Finding appropriate genes
- Limited number of character states
- Analytical ambiguities
- Not available for fossils

Genetics alone will never be enough
Fukami et al- good news:

- In general mt data agreed with nuclear data
- Scleractinia are monophyletic
- Complex, Pocilloporidae, Robust as groups
- Pocilloporids with distinct molecular characters- a unique clade

Bad news

- Faviidae- throughout the Robust corals; all over the place
- Mussidae- also throughout the Robust corals;
- Pectiniidae- not monophyletic- robust
- Merulinidae- not monophyletic- robust
- Poritidae- complex
- Agariciidae- some not with others in complex
- Families with reps in both major clades
    - Euphyllids
    - Oculinidae
    - Meandrinids- Ctenella in complex, others in robust
    - Siderastreidae
    - Astrocoeniidae

Most of families polyphyletic- a mess- need to be revised
Need to start to come to terms with some of the implications
What is grouping together? What defines these genera that are coming together? Should they be considered a family?
What morphological data makes sense in light of molecular data?
Implications

- Marine biodiversity hotspots: Caribbean ranks low but 5 deep lineages are restricted to Atlantic;
- Important to establish a new taxonomy to get this info in use by ecologists and conservation biologists

Discussion:

Pichon: makes sense and a good starting point; very common species that should be included in analyses
Come up with list of high priority taxa that need to be included would be a good thing to come up with in this workshop- importance of looking at type species

- Lathuiliere: Paradoxical that families are polyphyletic so need morphological analysis of families but then how to choose which taxa to describe

Importance of keeping voucher specimens from molecular data
Roniewicz: what to do about family names?
Budd: Favia fragum is type species for Faviidae; Mussa angulosa type for Mussidae- both Atlantic species; dealing with these issues with monograph in prep
Ecologists want names- they don't care about relationships
Use reverse taxonomy
The sooner we can get things out where we have a good sense that they are fairly robust- can't wait for 20-30 years to get all the data
Need to provide a useful tool for non-systematists

12-1:30pm: LUNCH

Monday PM (Waldo Schmitt Room, W218-B):

1:30-3pm: Primer on morphology, target audience= molecular workers
-Biological sense of microstructural analysis: from crystal arrangement to genes
[Stolarski, 30 minutes]

Show a panorama of different approaches to understand microstructure- to understand exactly what we are seeing

The crystal morphology is dependent on polymers present

Fish otoliths- a single protein controls which polymers are laid down (calcite vs. aragonite) and what shape they take; powerful influence of proteins on calcification
Molluscs: prismatic vs nacre polymorphs- trigger is different protein that starts with
For many years corals treated as inorganic skeletons- no influence of organic elements; corals don't have a lot of control on calcification- the paradigm- the spherulitic model
Will argue that stony corals are not stone

- Ex of Desmophyllum dianthus;
- A journey from macromorphology to microstructures
- Remove a septum: transverse section; see arrangement of crystals
- Longitudinal section- see a continuation of layers growing up in center of rapid accretion;
- Look deeper- transverse section of calcification centers and thickening deposits under greater magnification- see fibers

- TEM of fibers a bit distant from centers- behave like single crystals except that there are distortions in many places;
- Understanding the shape of the crystal- can be organic polymers that link nanocrystals and become transformed into mineral bridge;
- Bridged nanocrystals- submitted ms- Porites with TEM also see distortions- see cavities that are filled with organics; nanograins can be seen to be continuous with organics- a big surprise- were expecting a big difference between two regions
- Organics from biomineralization process are involved in crystallization
- Organic components at microstructural level- with fluorescence can see that organics exist in calcification centers; skeleton is full of polysaccharides in the fibers; polysaccharides can initiate calcification;
- Organics both proteins and polysaccharides at a number of levels; different organization of trace elements as well. Indicates that coral is controlling how calcification is happening
- Experiment with 86Sr in s/w- no space between calcoblastic ectoderm and skeleton where calcification taking place- coral knows precisely where to lay down the skeleton- the traditional model of calcification not supported- it is the coral that is controlling formation of the skeleton
- Wells' figure on septal evolution
- Flabellum has a very particular kind of microarchitecture- 'scale-like structure'- if you look at this microstructure magnified see scale like groups of fiber around centers of calcification; under epifluorescence see that scales are covered by organics
- If you look at fossil Flabellum see the same kind of scale like microstructure
- Guynia only modern coral with a very smooth microarchitecture
- Caryophyllids- illustration of importance of microarchitectural approach

Pocillopora with a very distinct microarchitecture

- Galaxea again a particular structure
- Acropora again a distinct microarchitecture
- Anthemiphyllia also distinct
- Gardineria- also a different kind of microarchitecture
- Stolarski, Benzoni and Stefani: fungiids- Cycloseris- pennulae in robust corals- but not clear in all fungiids however if you look at the microarchitecture more closely can see some resemblance
- Microstructural and microarchitectural characters have to be examined together with macroscale and molecular characters
- Believes that many types of microstructures are highly conservative and are not environmentally influenced

-Macromorphology, micromorphology, and microstructure using faviids and mussids as examples [Budd, 30 minutes]

Macromorphology- 3 D observations with light microscope; size and shape of many features related to corallite architecture, corallite integration,

Micromorphology- 3D using SEM on

Fukami et al tree- clades 17-21- character mapping- favids and mussids

Has scored 67 taxa

Macromorphology analyses

- Clade 17, 19, 20 characters all over the place; not diagnositon
- So if you go look at Vaughan and Wells 1943- key to families- higher level groupings based on microfeatures crude and coarsely defined- Wells only used a light microscope; macro characters used of lower level groupings, and distinctions between genera;
- Budd used 21 macro char; ex of 5; mapped onto molecular tree; evaluated with consistency index and retention index
    - Calice or valley width- overall not good but works within smaller clades
    - Problems due to polytomies; can she use trees from different genes
    - Number of septal cycles- all over the place- noise
    - Budding geometry- some resolution of subclades within major clades
    - Some info but a lot of homoplasy so need to use many char at same time and use a combo of char

Micromorphology: shapes of teeth and granules along the margins and faces of septa; devolopment of primary and secondary axes and thickening depositis; 13 characters in analyses of faviids and mussids

- Tooth outline- more resolution at base of tree-
- Tooth orientation- can clearly distinguish atlantic favids
- Tooh shape if compound- distinguishes pacific faviida
- Tooth height-some signal but a lot of mess'
- Perhaps need to weight characters and throw some out?
- Granule shape- some signal

Microstructure: arrangements of centers and fibers within septa and the corallite wall

- 12 microstructural char in analyses
- septotheca diagnostic of some clades
- trabeculotheca some diagnostic
- thickening deposits some info
- perpendicular crosses

If you use a combo of char for Big Messidae can get a diagnosis for subclades suggesting that subclades may be genera

Micromorphology gives highest levels in CI and RI

Combined molecular and morphologic data- support indices from molecules higher at base of tree; morphology better for tips; combined gives a well resolved tree

3-3:15pm: COFFEE BREAK

-An overview of the morphologic glossary [Johnson & Rosen, 30 minutes]

This talk really about developing a glossary for the treatise- should be a group effort

Atlas of Scleractinian Morphology- still online

Do we need a glossary? Dictionary? Atlas?

Wants to be able to identify things from a diagnosis

A glossary is good for lots of things- want to design something that is relatively general that can be adapted for a whole range of uses

What is a term? A structure, a process, defined standard orientations

Terms often associated with a qualifier

There is an existing glossary in the Corallosphere- any author can write definitions

3:15-3:45pm: Monophyly of the Scleractinia (molecular perspective) [Chen]

Hexacorallians: Zoanthiniaria, Actiniaria, Corallimorpharia, Scleractinia
Corallimorpharia: 4 families, 12 genera, 50 spp
Sideractiidae, Corallimorphidae, Ricordeidae, Discosomatidae
Scleractinia and Corallimorpharia are very similar structurally except for skeleton
Stanley's naked coral hypothesis: 3 scenarios- Simple, Paraphyletic, Polyphyletic
Historical review of molecular approaches

- Fautin and Lowenstein 1992: scler ancestral to actin and corallomorphs- corallimorphs and actinians had multiple origins from corals
- Chen et al 1995; Veron et al 1996: 28S; monophyletic scleractinia; descent from anemone-like ancestor; see complex and robust corals
- Mt data from Romano and Palumbi, Chen et al 2002; confirmation of two clades;
- Cuif et al 2003 28S 40 spp; see two clades
- Nuclear data Berntson et al 1999; Daly et al 2003; supports scleractinian monophyly with corallimorphs as sister group
- Add azooxanthellate taxa same thing
- Fukami data- corallimorphs monophyletic group sister to Scleractinia

Mitogenomic trees: Corallimorphs embedded in complex corals Medina et al
Lin et al (in prep)- 38 mt genomes; Bayesian trees; recover monophyletic scleractinia; pocilloporids sister group to robust corals
Gene rearrangement in mt genomes

- Conserved scleractinian mitogenome gene order

Importance of taxon sampling
Need mt genomes from azoox and from corallimorphs

4:50-5:20pm: The "naked coral" hypothesis [Stanley]

skeleton integral part of scleractinians
Hand 1966 suggested that actiniaria and corallimorphs were derived from Scleractinia due to paired mesenteries which would be derived from septa
Problematic origin and search for scleractinians progenitors
Appearance of first scleractinians in mid-triassic; diverse, complex; had to exist before then
Possible ancestors

- Rugosan ancestor- but a 10 my gap before Scleractinia
- Scleractiniamorphs- Paleozoic scleractinians? Presumably aragonite; 6 fold septa- Ezaki 1998
- Soft bodied ancestors-

Proposal of naked coral hypothesis- that a coral skeleton is ephemeral with regard to calcification
There are some fossil anemones- at least one example

A close relationship between scleractinia and corallimorpharia; see great similarity especially with fungiids
Example of naked foraminifers- other groups have an ephemeral skeleton
Medina et al work supported the hypothesis that corallimorphs are naked corals
Romano and Palumbi work supports naked corallimorphs
Why naked? Physiological responses to changing ocean chemistry?
Or a physio-chemical consequence of ocean acidification- this occurred numbersous times in the fossil record
Geochemical consequences

4:15-4:50pm: Relationships between zooxanthellate and azooxanthellate corals , target audience= zoox coral workers [Kitahara, Cairns, Miller, Stolarski];

How do azooxanthellate deep water corals fit into the order?
710 azoox corals of which 615 are deep water
28 scleractinian publications- 4 molecular studies including dw spp
Markers: cox1, 16S, 12S
Trying to get 18S and 28S
MP, ML tree with bootstraps; Bayesian analysis
16S: 162 scleractnians of which 113 azoox
COX1:222 scler, 75 azooxanthellates
Samples of Gardineria 16S, COX1, 12S- fall outside scleractinia-basal to the rest of Scleractinia?
Micrabaciidae- more basal than Gardineria, outside other scleractinians- slightly different signal from different markers; distinct microstructure as well
Dactylotrochus cervicornis falls out with Agariciids- reverse taxonomy shows how it is related to agariciids- has similarities
Dendrophylliidae- monophyletic; and closely related to poritids
Flabellidae- several spp; not enough signal at genus level; but supports a monophyletic family; maybe Placotrochus is not a flabellid
Turbinoliidae- interstitial habitat within sand deep sea substrates;
Fungicacyathidae- monophyletic; sister to tubinoliids
Anthemiphylliidae- a robust coral; most basal within robust corals perhaps- unclear; groups with a caryophylliid clade; share microstuctural characters but some are robust, some complex
Caryophylliid- most problematic- found in every environment;

- Deltocyathus- can only get coI- can't sequence from 16S; sister group to Anthemiphylliidae
- Another group basal within robust corals; a mix of genera;
- Solitary corals with 16S data- Trochocyathus- but sister group difficult to understand
- A large caryophylliid clade

Oculinidae with Galaxea with complex euphyllids; madrepora by itself; Oculina as sister group to caryophyllids
5 Families with zoox and azoox representatives
These analyses indicate a deeper evolutionary origins
Did Scleractinian fist appear in deep water as solitary azoox morphs and then colonize shallow water
Most families monophyletic
Caryophyllids and oculinids probably represent more than 1 family
Convergent evolution of some macromorphol characters

Continued examination of Anthemiphyllidae
All analyses on single genes- no combined analyses

followed by a brief presentation [Barbeitos]

Evolution of coloniality in scleractinians
Overlapping dataset with 97 samples; 85 spp; 64 genera; 18 families; ¾ corallimorph families
Use of secondary structure- improves alignment; can take into account compensatory mutations;
Problematic position of Pocillopora due to long branch attraction to outgroup

General discussion from the day:

6:30pm: DINNER

Tuesday June 16

Focus for the day: Robust –vs- complex corals (? Two major suborders)

Tuesday AM (Waldo Schmitt Room, W218-B)*:* Recent corals

8:30-9:00 am: An overview of the fossil record and phylogenies based on paleontological data, target audience= molecular workers [Roniewicz & Stolarski]

Ewa

Review of traditional classifications and molecular classifications

Taxonomy and classification of fossils

- Focus on microstructural and architectural characters
- Diagenesis results in obliteration of primary skeletal structure
- Well preserved aragonitic skeletons are rare
- Microstructure- elementary units of the skeleton; skeletal fibers

Alloiteau 1950-1980 Microstructural school

Examinations of microstructural characters are consistent with molecular results

Wells 1956, Veron 1996- uncritical approach to fossil data

Roniewicz and Morycowa 1993:

- Microstructural tracts?

Paleozoic scleractiniamorphs as ancestors to Scleractinia?

- Late Ordovician samples Kilbuchophylliidae
- Late Permian Numidiaphylliidae
- Middle Permian- coral with septal spines

First scleractinians in the west and east of Tethys- earliest finds are rare-include 20 genera; not solitary; very diverse in growth forms and architecture

Next microstructural window in the Cretaceous

Characters concordant with robust/complex in Triassic corals?

- Septal paddles in robust

Microsolenid corals don't fit with either group?

Other separate clades?

Back to microstructural scheme:

- 4 fold division
- not suborders- don't know

9:00-9:30am: An introduction to robust –vs- complex corals [Romano]

9:30-10am: Morphological comparisons using traditional families that include both robust and complex corals (the main objective is to identify diagnostic morphologic characters that can be used to distinguish robust –vs- complex corals in the fossil record)

(1) Siderastreids: *Siderastrea* (complex) –vs- *Psammocora*/*Coscinaraea* (robust) [Benzoni, 30 minutes]

Description of the family Vaughan and Wells 1943

radians is the type for the family

type is lost

9 genera depending on who you consult

Psammocora not always in Siderastreidae- was at one point in its own family
Oulastraea usually in Faviidae, V&W put it in Agariciidae; C&B in Siderastreidae
Xisashisiderastrea?
Veron has 6 genera
Psammocora in xlade XI but throughout the clade- 3 separate clades
Coscinaraea in clade XI but in 2 different places one with fungiids: so look at internal structure; P explanulata and C. wellsi have fulturae which is found in fungiids
Can make further sense of Psammocora when more closely look at septal structure, compared in skeleton and living specimens; also when you go back to orginal descriptions
Can get important info from tissues
Can find distinct differences between clade IX and XI- several different characters that hold
Enclosed petaloid septa go back to Mesozoic corals- just has to be more linkage between paleontologists and recent workers
Still problems with Leptastrea in the fungiids
Oulastrea cripata another problem- doesn't 'look' like a siderastreid
Craterastrea (Red Sea but from deeper, 30m, and Leptoseris very different in septal structure

10-12pm with coffee break from 10:30-10:45am

(2) Discussion of other families (based mostly on Recent corals) [moderators/recorders= Klaus & Benzoni]

-Astrocoeniids [Klaus]: *Stephanocoenia* (complex) –vs- *Madracis*/*Stylocoeniella* (robust)
7 genera in both families; Madracis and Palauastrea have moved around
Both in Astrocoeniina
Wells 1956 definition
Madracis shouldn't have been moved and belongs in Pocillorpoids and Stylocoeniella is a pocilloporid
Madracis more variable in nature- prominent septa; plocoid;
- During discussion became apparent that definition of wall structures needs to be clarified; and use of cerioid/plocoid imprecise

-Oculinids [Kitahara]: *Oculina/Cladocora* (robust) –vs- *Galaxea* (complex)

Wells description
10 recent genera- shallow and deep- some zoox, some azoox,some both
some in complex some in robust
Galaxea and Achrelia in complex
Madrepora and Oculina in robust
Jarek explanation of wall structures

- marginotheca vs. epitheca: longitudinal section through either you see the same thing- identical; see a rapid accretion center or zone where top part is growing faster than sides; in transverse section u/light microscope see a difference b/c in epitheca the centers are not visible but in marginotheca the centers are clear
- trabeculae traditionally region where there are rapid deposits but no boundary there so doesn't really exist; he won't use the term trabeculae- is confused with it;
- trabeculothecal wall is OK- wall formed between the septa- this term ok to use

- marginotheca when the theca forms around new septa forming between older septa
- septotheca when wall comes from the septa
- but this is a developmental sequence
- wall structures developed for solitary corals and so difficult to apply these terms to more complicated situation found in colonial corals
- synapticulothecal wall is completely different- septa form granulae on sides that during ontogeny eventually merge- look like ladders in a longitudinal secton
- parathecal wall
- see Barnes 1972 for excellent explanation of epitheca- also in the French treatise
- transition from marginotheca to trabeculotheca in most corals

12-1:30pm: LUNCH

-Euphyllids [Hoeksema]: *Physogyra* (robust) –vs- *Euphyllia* (complex)
Euphyllia in 2 places in V- complex; fleshy
Physogyra in robust- single species? Fleshy; In clade X!V near Blastomussa
Not much difference in septal structure for these two in terms of robust and complex
Catalyphyllia fleshy
Nemenzophyllia fleshy
Plerogyra- huge solid septa, fine margins, fine granules, fleshy
At microstructural level they look very similar Physogyra and Euphyllia

-*Blastomussa*/*Parasimplastrea* [Benzoni, Stefani]

Oddball clade XIV groups with Plesiastrea and Physogyra
Parasimplastrea poorly known; limited to north Indian Ocean; perhaps similar to Blastomussa but classified as an oculinid and then as mussid?
Robust corals
With additional Benzoni sequences the two continue to group together
If include faviids and mussids from Yemen still get Blastomussa and Parasimplastrea but then…polymorphis in nuc rDNA 5.8, 18, 28 without ITS;
Septal morphology comparison of Blastomussa and Parasimplastrea- different septal cycle number?
One sp of Blastomussa more closely related to Parasimplastrea than to other sp of Blastomussa
Look at soft body characters- 2 spp with different numbers of cycles
But in Chevalier clarifies this
Columella pretty much the same
A mussidae not with the mussidae and a faviidae not with the faviidae but otherwise not clear what is going on- molecular results not robust- need further analyses

-Meandrinids [Budd]: *Ctenella* (complex) –vs- other meandrinids (robust)

Highly variable as a family
Ctenella in Complex corals; other meandrinids robust; Dendrogyra and Dichocoenia robust
Ctenella chaguis- skeleton passed around- looks superficially like a massive Dendrogyra
Dichocoenia looks distinct from Eusmilia and Ctenella

General discussion- are there any characters that distinguish complex vs. robust
Nothing jumps out though in general seems to fit the complex/robust general characters

Tuesday PM (Waldo Schmitt Room, W218-B): Fossil corals and more discussion

(4) Other morphological comparisons

-1:30-2pm: Acroporids (complex): acroporids –vs- *Alveopora* (and the poritids) [Wallace & Pichon]

Carden:
Traditional acroporidae with inclusion of Alveopora
7 genera Acropora, Isopora, Astreopora,Montipora/Anacropora, Dendracis, + Alveopora
all members have been present in the Caribbean in the past- only Acropora today
Does Alveopora fit the acroporidae profile- extratentacular budding; synapticular walls and septa; spiniform septa or laminae; No extensive coenosteum; septa in 2 cycles yes and no- similar to Astreopora, Montipora; little or no columella; little or no dissepiments; Polyps with 12 tentacles; similar for one species in reproductive morphology and mode- similar to Isopora
Alveopora is as acroporid as other acroporids and not poritid like poritids
Genus by genus review

- Acropora- variability in coenosteum structure; using 30 variable morphological characters in conjunction with molecular data
- Isopora- type species palifera; variable number of axial corallites; hermaphroditic brooders, stalked gonads; spinoid coenosteum; Found in Caribbean fossil record
- Montipora- neglected- almost as diverse as Acropora- main variability is coenosteal; immersed corallites without wall; some cryptic species exist; spawns twice/year; extraordinary variability of coenosteum;
- Dendracis
- Astropora- starting to get more exciting; some similar to Isopora- branching; characteristic coenosteum

Michel Pichon: Poritidae
140+ nominal species, 25 in Goniopora;
Removal of Alveopora makes the situation much simpler
Porous network of simple synapticulae; synapticular septa
Two new genera- Poritiopora (Veron) and Machadoporites (Nemesio- from Madagascar?)
Distinctive septal arrangement
Large number of Porites spp that are inconspicuous or uncommon
Poritid structures- vertical trabeculae linked together by horizontal elements; highly perforate septal structure; synapticular rings that are developed at various planes connecting the trabeculae;

Goniopora-
Machadoporites tantillus- not typical septal structure- very small- a few cm;
Napopora- from Society Islands where it is very common;
Poritipora polyformous- don't know enough about it
No major genus level problems; need to readdress issue of genus/subgenus
Sometimes the polyps can be useful- especially useful for Goniopora- color of oral disk and when expanded.

3-3:15pm: COFFEE BREAK

-2pm-2:30pm: Fungiids (robust): fungiids –vs- *Oulastrea* & *Leptastrea* [Hoeksema & Gittenberger]
laminar septa connected by fulturae (lateral bar-like elements); mono or polystomatous; shallow water Indo Pacific
Many species can be traced back before Pliocene- even before the quaternary
Cladogram based on morphological characters
Fulturae a synapomorphy for fungiids although now also found in Psammocora and Coscinarea- intruders to the fungiidae
Another characteristic is detachment then reversals in 3 different clades
Secondary mouths arise 4 times in the group- different ways to be polystomatous
Trends from round to oval to elongate- again numerous times; useful for distinguishing genera
Corallum wall perforate in 6 lineages- used for distinguishing spp
Autotomy only found in Cycloseris group but fragmentation in every spp- some more frequent than other
Large tentacles can be useful for distinguishing species- 2 lineages
Gittenberger molecular analysis- 3 spp shift from one genus to another- minor changes; subgenera raised; one synonymized;
Leptastrea pruinosa groups in clade with Fungiids- extratentacular budding, no cpd synapticulae- no place in fungiides
Oulastrea- extracalicular budding, no fulturae- doesn't belong

(5) the fossil record of robust –vs- complex corals
- **2:30-3pm:** the late Cenozoic fossil record [Johnson; 30 minutes]

Coral diversity through the Cenozoic
How coral reefs have responded to global changes in earth history that have different effects in different regions
Most of work based in Caribbean
Rise of Isthmus through the Neogene in Caribbean
Indonesian throughflow from Oligocene constricted
Extensive reef building in Oligocene in Caribbean- then reef gap in Miocene/Plocene; switch on in late Pliocene
Opposite story in SE Asia; regional carbonate deposition- forams in Oligocene; early Miocene switch to reef building until present
Everything based on datasets from firsthand observations

Caribbean since late Oligocene- 7000 occurrences all around ; collections from old and new exposures; focusing on poorly known parts of the record; working on good age dates; addressing sampling problems especially in Trinidad- constantly finding new taxa

Picture in SE Asia from publications from late19th and early 20th century; when start reexamining the specimens that these publications are based on there area a lot of changes- updates- the samples classified based on Creaceous European; also few specimens/genus

In Pacific a Fossil/Recent disconnect- taxonomic work done by modern workers- doesn't include fossil taxa

Regional Carribean Zooxanthellate coral diversity- late Oligocene and Recent have lower diversity than late Pliocene even though that was a time of less reef building; lots of spp went extinct about 1-2 mya; another at Oligocene/Miocene boundary; Apparent diversity due to increased sampling but extinction was real

SE Asia genera- some very long ranging; lots first occur in early Miocene and persist today; low diversity in Oligocene; High diversity in Recent

Robust vs. complex?

- Since late Oligocene 67% robust taxa, more common as well- in Caribbean
- Was there selectivity for either group?
- SE asia same kind of split
- Robust taxa increased more in diversity and then go extinct 1-2 mya- living in soft bottomed communities; in Caribbean
- SE Asia- robust taxa stay pretty much the same
- But what about abundance? Some evidence that in Caribbean complex taxa became more dominant after extinction event 1-2 mya

Doesn't see evidence for pulses of diversification in Caribean

Were pulses of extinction- no evidence in SE Asia

Two regions are out of phase in terms of reef building

In Caribbean have higher diversity in non-reef settings

- **3:15-3:45pm**: the early Cenozoic fossil record [Stemann; 30 minutes]

complex: synapticulae; porosity of septa and coenosteum

robust: size and complexity of septal dentition; corallite size, meandroid habit; large solitary

Problem taxa that lead to problems in fossil taxa- astrocoeniids, siderastreids, thamnastereids, agariciids

Modern morphologic distinction between robust complex may be greater than that of the past

Robust

- Faviids and big messids that are well behaved; Favia, Hydnophora, Leptoria
- Fungiids only a few stretch back into Eocene
- Pocilloporids stretch well back and not much variation in genera
- Generally missing families: Mussids, Pectinids, Meandrinids don't go far back
- Groups with expanded variance- Carib Montastraea, Diploastrea
- Extinct genera most difficult- starting from Eocene

Good complex corals

- Families with good records through Cenozoic- dendrophyllids, poritids, acroporids
- Extinct families- Actinacididae-fairly common but a lot like a lot of poritids

Problem complex corals
- Astrocoeniidae
- Agarciidae and Siderastreidae
- Extinct families- Stylinidae; siderastreids

Problematic groups similar to species in Clade XI

- **3:45-4:15pm**: the Mesozoic fossil record [Lathuiliere; 30 minutes]

Used 'reverse' taxonomy to try to make sense of Mesozoic fossil record in terms of robust and complex- used literature from data for same character matrix as from my Science paper

No clear solutions- sees no relation between skeleton and these two groups

So looked from a different perspective;
- fungiid septa like Montlivaltids from Mesozoic
- cycloseris belongs to microsolenids from Mesozoic

need a solid link between DNA trees and skeletal characters

need to study DNA and skeleton from same samples

need to include microstructure and microarchitecture

need to know more about variability of skeletal characters

Following tracks from Mesozoic to Recent?
- Need outgroup- what is a Scleractinia- Wells' definition is a problem
- Don't know how to define skeletal character
- Problem of Scleractiniamorpha- only bifurcating septa puts it apart from Scleractinia
- Hydrosclera antoher boundary problem-
- Can't define Scleractinia

Nothing from the Cretaceous continues into the present- groups that may be Scleractinia depending on who you believe.

Triassic experiments of Scleractinia
- Protoheterastreidae
- Reimaniphyllidae/Distichophyllidae
- Volzeidae
- Margarophylliidae
- Procyclolitidae
- Cuifastreidae
- Astraeomorphidae
- Actiastreidae
- Stylophyllidae

Triassic panorama looks more like a lawn

Jurassic success of Scleractinia
- Montlivaltiidae with trabeculae, teeth on septum
- Stylinidae with distinct characters
- Rhipidogyridae again with distinct characters
- Microsolenina- big success with pennulae
- Dermosmilidae with pennula like structures;
- Thamnasteriidae with special ornamentation
- Others as well

Labeled robust and complex on Roniewicz's microstructural phylogeny- all mixed up- need to reevaluate what we understand about microstructure
Our knowledge on homogeneity of families is not reliable enough to create a stable phylogeny
Too early for Mesozoic phylogeny

4:15-5:30pm Discussion of breakout groups and selection of families (taxa) that will be coded during the workshop [moderator= Budd]

6:30pm: DINNER

Wednesday June 17

Focus for the day: Phylogenetic analysis of scleractinian families (breakout groups)

8:30 am Discussion of breakout groups and selection of families (taxa) that will be coded during the workshop [moderator= Budd]

come back at 10:45 with 5-10 characters and 5-10 taxa; then we'll all agree what will be coded in terms of characters and taxa

initial discussions will be according to Fukami clades

every group should deal with one azooxanthellate family, and one fossil family

Marcelo's tree with azooxanthellate taxa

Choose 5-10 families for which we have images

Should choose 5-10 genera representative of families

Characters- from diagnoses people sent Nancy- are from the Corallosphere glossary; But diagnoses are not consistent- people used different characters, different terms; character homology is dubious for some characters

AM & PM: Breakout into 4 working groups (taxonomically defined)

- These working groups will construct a morphologic character matrix for ~100 families
- For each group of characters in the morphologic glossary, each working group will code a subset of families
- Each working group will present a 10-minute progress report at 10:45am and 4pm (to make sure that everyone is on the same page)

This character matrix will be used in the phylogenetic analysis of families. Coding it will give people experience using the morphologic glossary.

Tentative groups:

Group 1, room W-105 (chair's office): Complex corals (Fungiacyathidae, Dendrophylliidae, Poritidae, Acroporidae, Flabellidae, etc): Cairns, Chen, Darrell, Pichon (moderator), Romano, Roniewicz, Stemann, Wallace, (recorder) [8]

Group 2, room W-218 (regular meeting room): Robust corals-I (Pocilloporidae, Astrocoeniidae, Caryophylliidae, Anthemiphyllidae, etc): Baron-Szabo, Kitahara, Klaus (recorder), Stanley, Stolarski (moderator) [5]

Group 3, room W-312 (mollusk library): Robust corals-2 (Fungiidae, Agariciidae, Siderastreidae, Meandrinidae, Euphyllidae, Oculinidae, Rhizangiidae, etc): Benzoni (moderator), Gittenberger (recorder), Hoeksema, Lathuiliere, Morrison, Rhodes, Stefani, Stemann [8]

Group 4: room W-106/7 (Knowlton office): Robust corals-3 (Faviidae, Mussidae, Pectiniidae, Mussidae, etc): Budd (moderator), Fukami (recorder), Huang, Johnson, Jung, Nunes, Rosen [7]

Floaters: Barbeitos, Knowlton

***Wednesday AM*:**

9-10:30am: Breakout groups (focus on selection and definition of characters)

Turbinoliidae as azooxanthellate- Turbinolinia? Type species

Fossil : Conophylliidae (exclusively Triassic); Actinacididae (Jurassic to Cenozoic)

Recent: Acroporidae, Poritidae, Agariciidae, Dendrophylliidae, Siderastreidae, Flabellidae, Euphylliidae
Conophylliidae characters:
Corallum type- colonial, solitary
Discussion and development of worksheet

10:30-10:45am: COFFEE BREAK
10:45-11:15am: Progress reports (Waldo Schmitt Room, W218-B); breakup groups will report on the characters that they would like to code
all group discussion
report from Jarek (Group 2): Robust 1
report from Bert (Group 3) Robust 2
report from Ken (Group 4) Robust 3
report from Michel (Group 1) Complex

Discussion of characters

11:15-12pm: Breakout groups (focus on coding taxa)
12-1:30pm: LUNCH

***Wednesday PM*:**
1:30-3pm: Breakout groups (focus on coding taxa)
3-3:15pm: COFFEE BREAK
3:15-4pm: Breakout groups
4-5pm: Progress reports (Waldo Schmitt Room, W218-B); each breakout group will present their character matrix
6:30pm: DINNER

Thursday June 18

Focus of the day: Treatise, Corallosphere, and EOL

***Thursday AM*:**

Francesca summary of the TARA Oceans expedition- 3 yrs around the world focus on plankton but at times will be doing reef collections; possibility of getting coral samples for morphological and molecular work; First year Indian Ocean- Chagos, Mayotte, Djibouti; Would be easier if we formed an association that could apply to use the material and work with it. www.taraoceans.org

9am-12pm with coffee break from 10:30-10:45am: Two alternatives (participants may choose one or the other):

(1) Alternative 1 ***(room 624, main building)***: Treatise on Invertebrate Paleontology (Cairns)

A. Volume 1: (morphology, classification, etc): progress report by Stolarski

B. Volume 2 (taxonomic):

1. Progress reports from group leaders (Cairns, Budd, Baron-Szabo, Lathuiliere, Roniewicz) e.g., who is in your group, how many genera are you responsible for, how many have you entered, what are problems with the system...
3. Report from Jill Hardesty on Treatise production
4. Discussion led by Ken Johnson on Corallosphere issues.

(2) Alternative 2 ***(Waldo Schmitt Room, W218-B)***: Discussion of unresolved issues in molecular analyses (Chen & Knowlton)

Nancy: Introductory remarks- suggestion to coordinate efforts where there are holes or areas that need work; Come up with a wish list?

4 markers COX1, 16S, Beta Tubulin, cyt B- maybe 28S (5' end, 1000 bp)

Hiro: Clade XIV (robust) lacking taxa

Blastomussa, Parasimplastrea, Plesiastrea, Physogyra, Plerogyra, Trochocyathus

- COXI, ITS Blastomussa, Parasimplastrea Franzoni lab; Cox 1 Blastomussa and Parasimplastrea share a single haplotype
- Marcelo says that Trochocyathus doesn't belong in this group at all but same sample 16S is in a different clade; Trochocyathus rhombolumina is in complex clade
- All long branches- maybe long branch attraction problem
- Have morphologists (Jarek) look carefully at these taxa with thin sections

Gittenberger Fungiidae- ITS,

Leptastrea as sister clade to Fungiidae or one clade- problems? As sister group OK but if it clusters within this would be really difficult to explain; with COI just looking at the alignment, there are certain characters that are in Leptastrea but not in the fungiids; Fabrizio has numerous Leptastrea spp.; need more nuclear data and molecular data from more Leptastrea species; Have morphologists look at these more closely as well

Pachyseris linked with Euphyllids?

- Need to look at other species?

- Could be a polyphyletic genus- some might be with agariciids, others not
- Fabrizio has a number of agariciid sequences from Yemen and New Caledonia

Palauastrea supposed to be in Astrocoeniidae- grouping with pocilloporids
Taxa for the Tree of Life analysis? Do we have necessary samples?
Big Messidae? No resolution?

- Severance single copy nuclear markers?
- Beta tubulin?
- X and Hellberg 2009 paper that just came out- scn markers

Listserve for molecular systematics? Flavia will set it up
Leaving azooxanthellates to those working on them
What about dating divergences? Not a good fossil record for deep water taxa

12-1:30pm: LUNCH

***Thursday PM (Computer Learning Center, EC-G29)*:**

12:30-1:30 pm
Working lunch to discuss the morphological character matrix.

1:30-2:30pm: Demo of EOL [Cyndy Parr]
2:30-3:30pm: BHL, Biodiversity Heritage Library [Tom Garnett]

3:30-3:45pm: COFFEE BREAK

3:45-4:15pm: Demo of Corallosphere, including how to input images [Johnson, Coffer]

includes all generic names used for Scleractinia
demonstration

4:15-4:45pm: Progress report from the molecular group, based on Thursday AM discussion [Chen]

CoralGene- listserve for coral molecular geneticists for information sharing
Want database of type species photo
Importance of Indian Ocean and Red Sea samples- lacking in current samples
Mt genome sequencing of Gardineria to construct mt genome tree
Molecular clock dating based on mt genome tree?
Individual clades and taxa that need to be examined:

- Clade 14 with Plesiastrea devientieri from Gulf of Aden
- Euphyllidae with Catalaphyllia, Nemezophyllia, Plerogyra- in the Chen lab
- Relationship between Leptastrea and Fungiids- need microstructure, more species, and nuclear markers
- Pachyseris- need morphological examination – Francesca?
- Paulastraea- is it in Astrocoeniidae or Pocilloporidae

- Azooxanthellate taxa- Trochocyathus and Plesiastrea- needs to be reexamined at molecular level

General comments- suggestions of more taxa to be included; put names on samples without a species name; resolve polytomies to assist in mapping; list of azooxanthellates that we would like to sample

2. Report from George Stanley on geographic menus

6:30pm: DINNER

Friday June 19

Focus of the day: Tours and final wrap-up

***Friday AM (begin in Waldo Schmitt Room, W218-B, at 8:30am to catch 9am shuttle to MSC)*:**

9am-12pm: Tours of collections [NMNH –or- MSC: Museum Support Center (depository of fossil collections and molecular lab)] and Ocean Hall; all participants touring MSC should be prepared to take a 30-minute shuttle to and from the facility

12-1:30pm: LUNCH

Friday PM (Waldo Schmitt Room, W218-B):

1:30-2pm: Coral Triangle vs. Mushroom Coral Triangle: corals as model groups in marine biodiversity research [Hoeksema]

coral triangle – different from other biogeographic boundaries
lots of symbiotic organisms on corals- many specific to their hosts
location of triangle has shifted – now towards the east- what is driving the shifts?
Mostly from Veron's data
Coral Triangle ecoregions: Green and Mous 2008
We don't know species richness patterns well enough to understand what is going on
Can learn more about the biogeographic patterns by studying the symbionts

2-2:30pm: Preliminary results of family phylogenetic analysis [Budd, Barbeitos]

Marcos: 34 characters, 42 taxa; 1 MPT; but only 3 groups with bootstrap report
No 2 clade structure
Complex corals seem to be grouping together

2:30-3pm: Discussion of action items (TBA) – future plans

Budd:
Additional taxa should be in the analysis? Added to the list
Need to do more with microstructure- need thin sections
Idea of posting an alternative classification system on Corallosphere so that it will feed into EOL

3-3:15pm: COFFEE BREAK

3:15-4pm: Continued discussion of action items (TBA) – future plans
4-5pm: EOL wrap-up and meeting evaluation survey

Assignment of people to get SEMs and thin-sections of specific taxa for a new revised morphological analysis

Characters?

Marcos will send out a copy
Meeting notes- Sandra and Alastair will send around meeting notes for people to add to
Brian will write a meeting report for Reef Encounter?
Nancy, Nancy and Steve will discuss the possibility of doing a TREE publication
Will be a report on the EOL blog
Session at Asian Coral Reef Society Meeting in Phuket in June 2010? Carden

6:30pm: DINNER