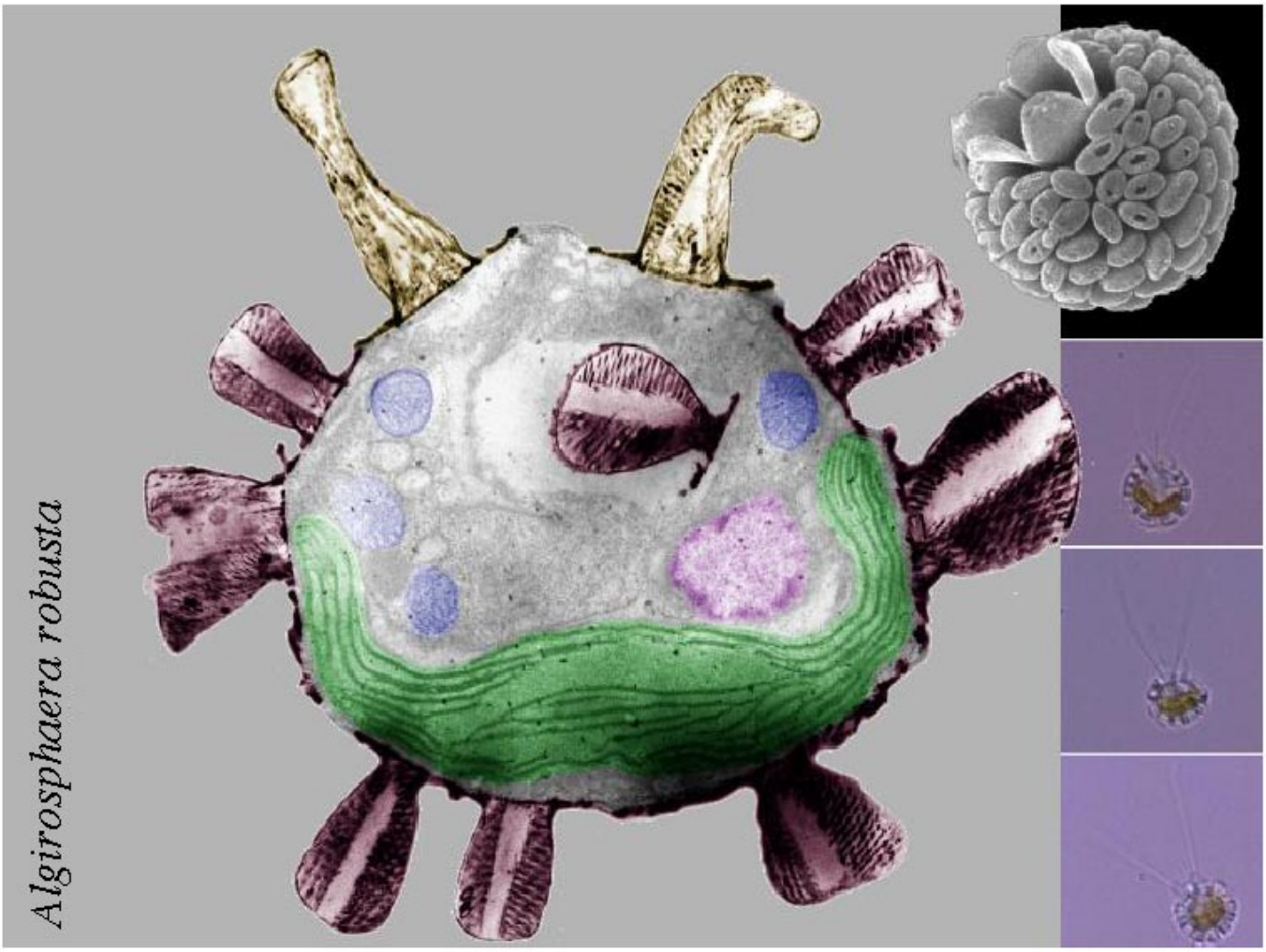
Coccolithophorid Evolutionary Biodiversity and Ecology Network

CODENET

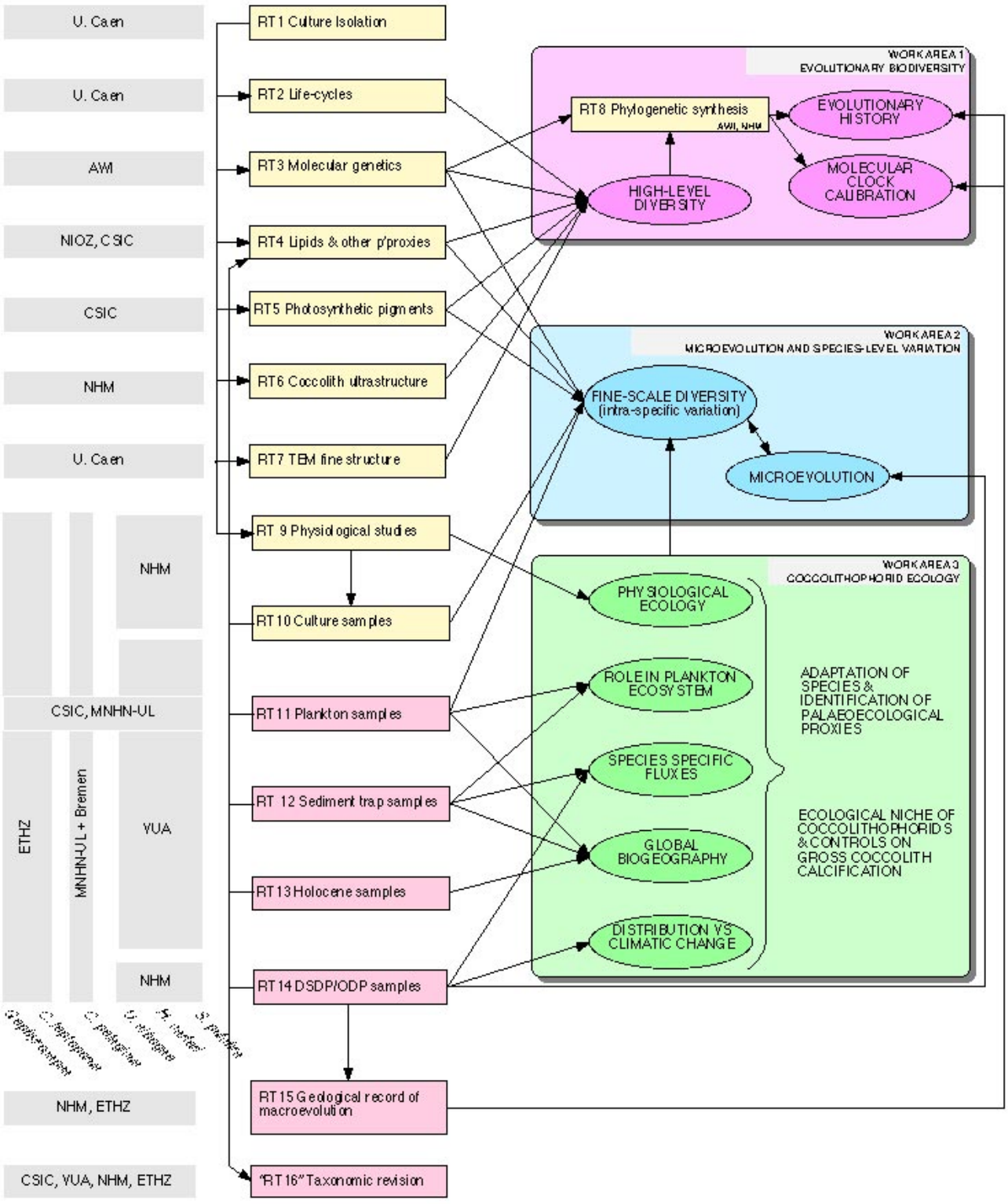
TMR Network ERBFMRX CT97 0113

Final Report

December 2001



Algirosphaera robusta - transmission electron microscope section from Ian Probert, false coloured by Markus Geisen for an exhibition of coccolithophore images in the NHM. Top right scanning electron micrograph, bottom right differential interference constrast light mocrographs.
One of the many unpredicted results of the project was isolation of this deep photic species, on a cruise organised by CISC Barcelona, and subsequent discovery that the hood-like extensions of the coccoliths were formed by a novel biomineralization process.



CODENET

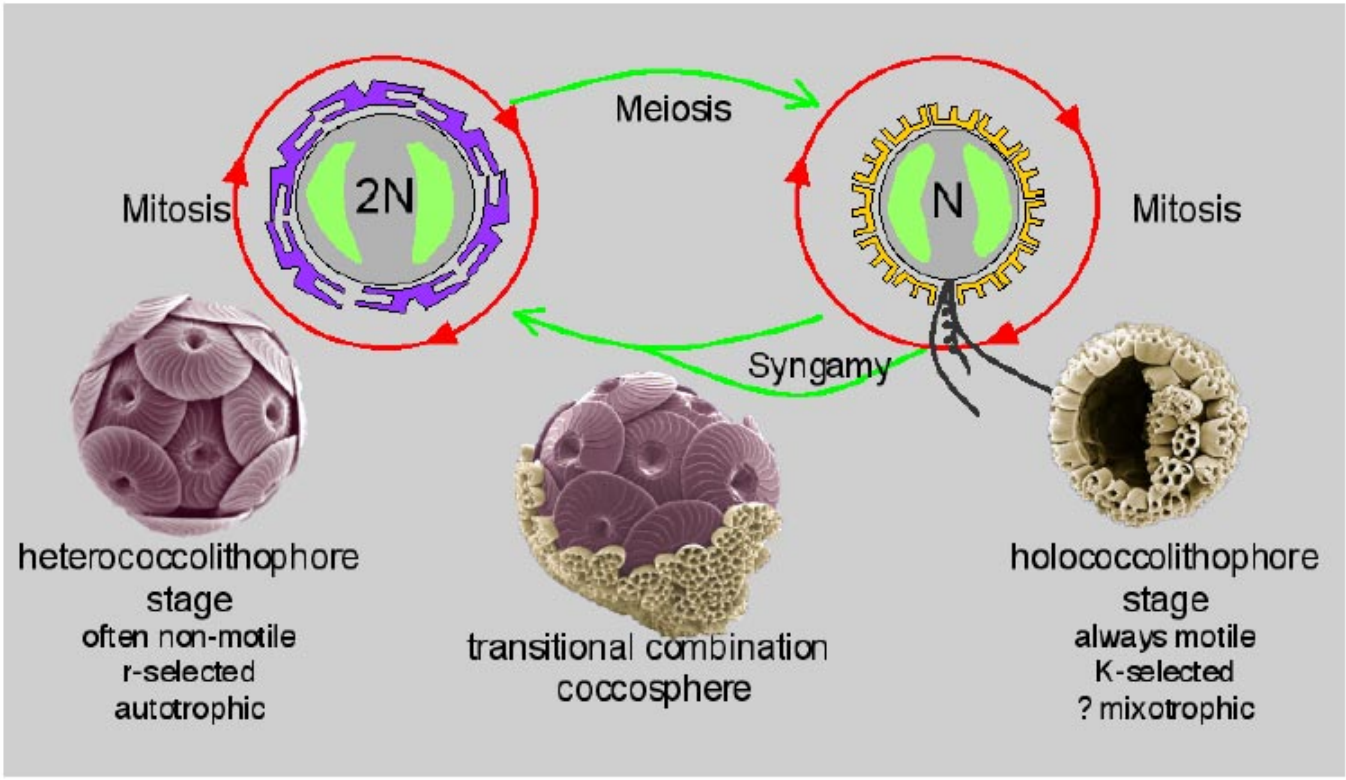
Fig. 1 CODENET - PROJECT OVERVIEW
Slightly redrawn from original version in proposal, to reflect additional research task RT16 and some extra linkages

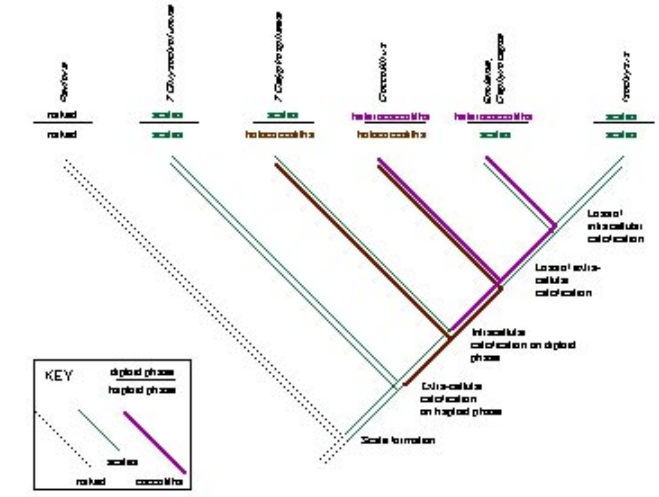
	Institution	Team	Participating scientists (with involvement in months during 1998–2001) Scientists in Chief listed first, CODENET funded YVRs in **bold**.	Staff scientists	Research students	Total staff scientists + students	Young Visiting Researchers	RT1. Culture isolation	RT2. Life-Cycles	RT3. Molecular genetics	RT4. Lipid biomarkers	RT4a Stable isotopes & Sr/Ca ratios	RT5. Photosynthetic pigments	RT6. Coccolith ultrastructure	RT7. TEM fine structure/cytology	RT8. Phylogenetic synthesis	RT9. Physiological characterisation	RT10. Intra-specific variation	RT11. Plankton samples	RT12. Sediment trap samples (Time)	RT13. Holocene samples (Biogeography)	RT14. Geological samples	RT15. Plankton/laboratory studies	
1	The Natural History Museum, London	NHM	J. Young (26), **M. Geisen** (42), F. Noverraz (1), K. Muller (3), P. Bown (UCL – 1), A. Howard* (1), A. Poulton* (Southampton – 1), S. Davis (Bristol – 1), A. Broerse (Sorbon/NHM 6), S. Gibbs (Cambridge/NHM 10), M. Hackfield* (3), E. Williamson* (3), B. Steel* (4), K.	38	19	57	42	MG BB	JY MG BB	*		*		JY MG KH	*	JY	JY MG KH BB	MG BS	MG AB MH EV	*	MG	MG SG	RD JY	NHM
2	Eidgenössische Technische Hochschule, Zürich	ETHZ	H. Thierstein (4), **S. Renaud** (24), **P. Quinn** (10), J. Bollmann (8), C. Klaas (24), K. von Salis (2), J. Henderiks* (2.5), M. Cortés* (2.5)	38	5	43	37	CK	MG								CK SR	JB CK SR RQ	CK SR RQ MC	JB	*	JB HF	KVS	ETHZ
3	Vrije Universiteit Amsterdam, Faculteit der Aardwetenschappen	FAA-VUA	J. van Hinte (3), S. Gessen (2.5), **P. Ziveri** (36), P. Westbroek (RUL – 2), A. Broerse* (9), A. Lototskaya* (4), sub-contractor A. Kleijne (8), E. Malinverno* (Milano – 6), S. Giunta* (Ancona – 6), B. Balestra* (Florence – 3)	15.5	37	52.5	36					PZ GG [illegible]							PZ AK EH BB	PZ AK AB	PZ AK BB	AL BB		FAA-VUA
4	Université de Caen Basse-Normandie	U. Caen	C. Billard (5), I. **Probert** (45), J. Fresnel (8), A. Houdan* (10.5)	15	10.5	25.5	45	CB JF IP	CB JF IP AH	*	*	*	*	*	CB JF IP	IP	IP AH		AH					U. Caen
5	Alfred-Wegener-Institute for Polar & Marine Research, Bremerhaven	AWI	L. Medlin (1), **A. Saez** (43), Y.A.R. Haas (Erlangen – 4.5), U. Riebesell (1.5)	13	0	13	43			LM NABH AS						LM	*							AWI
6	Consejo Superior de Investigaciones Científicas – Instituto de Ciencias del Mar, Barcelona	CSIC	M. Estrada (4), **K. van Lenning** (42), M. Latasa (2), J. Grimalt (2), B. Alonso (1.5), A. Palanques (1.5) L. Cros (22), R. Margalef (2), C. Pelejero* (8), S. Cervera* (4)	35	12	47	42	*	LC		JG		MG KVL CP SE				KVL EP		LC ME					CSIC
7	Museu Nacional de Historia Natural da Universidade de Lisboa	MNHN-UL	M. Cachão (10), M. T. Motta (3.5), M. Graça Firmino (1.5), S. Palma (1), A. Oliveira* (4.5), A. Narciso* (19), A. Duarte Silva* (15)	16	38.5	54.5	0	*									AGS	MC AGS	MC MTM MGF AGS		MC AB	MC AN		MNHN-UL
8	Nederlands Instituut voor Onderzoek der Zee	NIOZ	J. Sinninghe Damsté (2), **H. Kinkel** (36), J. de Leeuw (2), G. Versteegh (1), S. Schouten (2), + skilled technicians (4)	17	0	17	36				SS GR MK		*											NIOZ
8a	University of Bremen N.B. The contract was altered to formally include this team, within the NIOZ group	U. Bremen	K-H Baumann (8), C. Sprengel* (10), B. Boeckel* (19)	8	29	37												KHB BB	KHB CS BD	CS	KHB SB	KHB SB		U. Bremen
			TOTALS	194	151	345	281																	
			NOTES RUL – Leiden University UCL – University College London U. Erlangen – University of Erlangen Team participants from other institutes * Research students	Tenured & staff scientists	Students	Total, excluding YVRs	EU visiting researchers	RT1	RT2	RT3	RT4	RT4a	RT5	RT6	RT7	RT8	RT9	RT10	RT11	RT12	RT13	RT14	RT15	

MONTHS RESEARCH 1998–2001 / MONTHS SPENT IN PROJECT

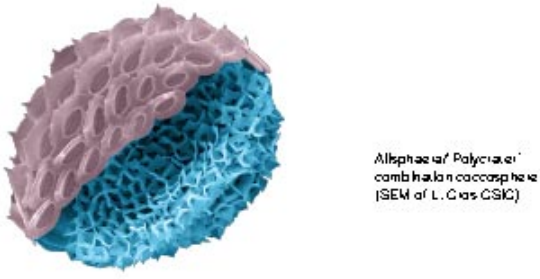
DIVISION OF RESEARCH TASKS BETWEEN TEAMS

* minor involvement by the team.

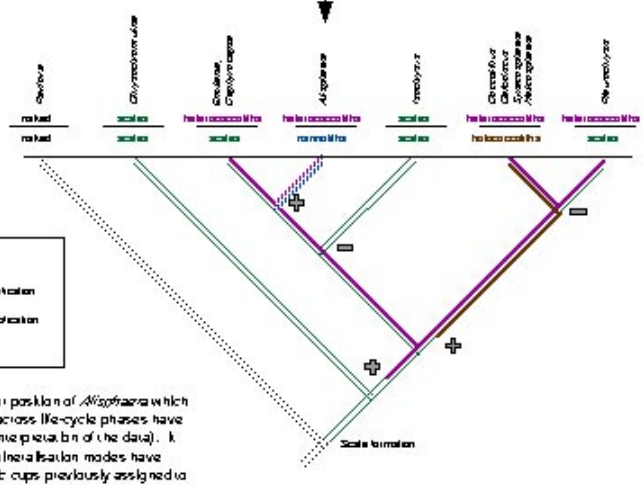




Prediction of the relationship of Haptophyte phylogeny and periplast formation processes. From Brown & Young (1997) and CODENET proposal

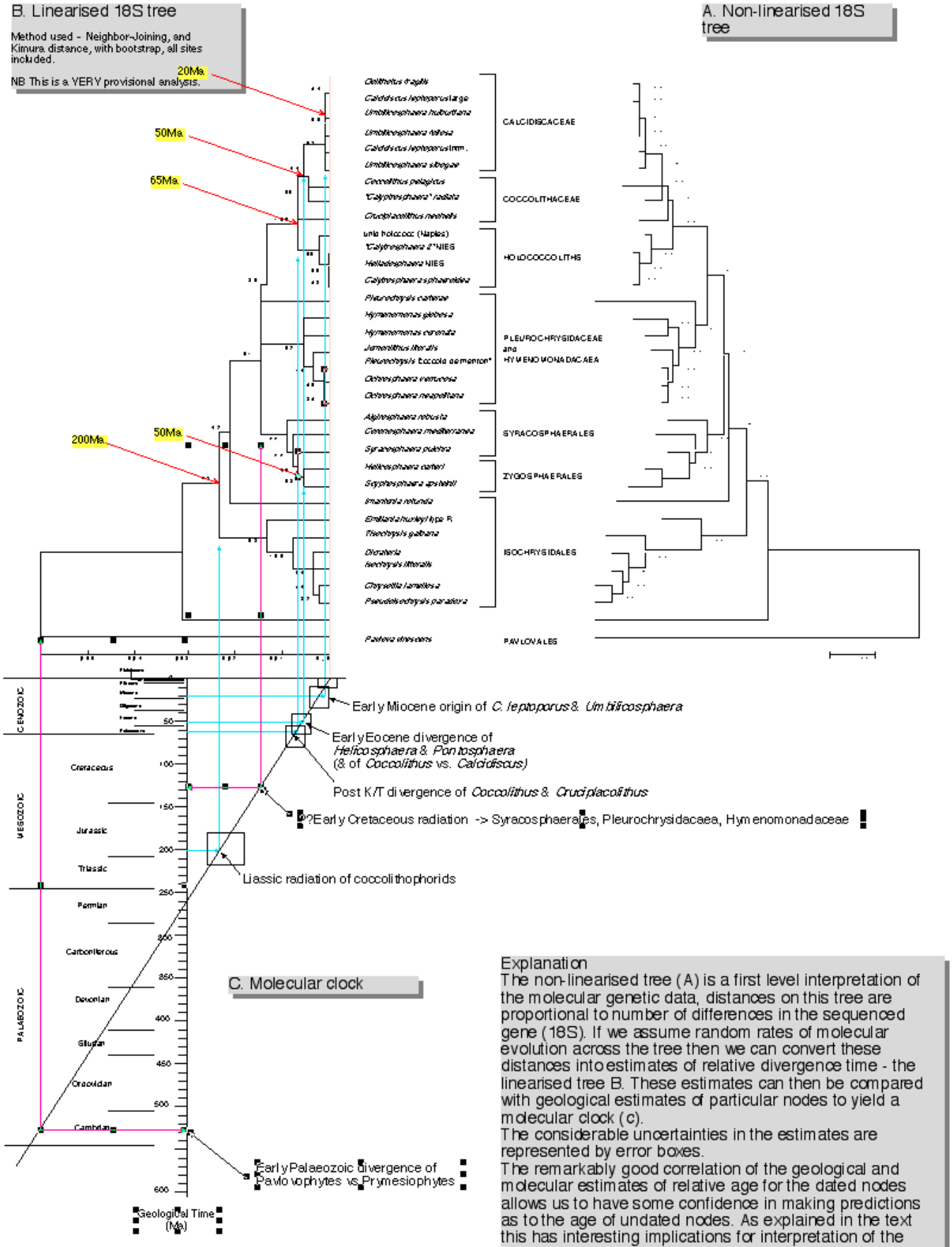


Allsphaera/ Polycrater combination coccosphere (SEM of L. Cros CSIC)



Outcome - relationship of periplast biomineralisation to phylogeny, based on molecular genetic data (except for position of *Algisphaera* which is speculative). The predictions that biomineralisation modes are conservative characters and differentiated across life-cycle phases have been fully supported. Contrary to predictions intracellular calcification evolved first (based on parsimonious interpretation of the data). It has subsequently been lost at least twice (*Isochrysis, Pleurochrysis*). In addition different haploid phase biomineralisation modes have evolved at least twice (holococcoliths and the non-homologous nannoliths of *Algisphaera* - these are aragonitic cups previously assigned to *Polycrater*).

Fig. 3 Coccolithophore life-cycles - outcome vs. prediction
Top figure shows the generalised model of coccolithophore life-cycle, this is essentially as predicted, by Billard (1994) although much more widespread than expected and with completely unpredicted combinations. Bottom two drawings - comparison of an almost entirely speculative phylogeny for calcification in haptophytes (as included in the proposal) and the proven picture, which follows the same basic pattern but with very different details.



Explanation

The non-linearised tree (A) is a first level interpretation of the molecular genetic data, distances on this tree are proportional to number of differences in the sequenced gene (18S). If we assume random rates of molecular evolution across the tree then we can convert these distances into estimates of relative divergence time - the linearised tree B. These estimates can then be compared with geological estimates of particular nodes to yield a molecular clock (c).

The considerable uncertainties in the estimates are represented by error boxes.

The remarkably good correlation of the geological and molecular estimates of relative age for the dated nodes allows us to have some confidence in making predictions as to the age of undated nodes. As explained in the text this has interesting implications for interpretation of the coccolith record of extinctions across the Cretceous/Tertiary boundary.

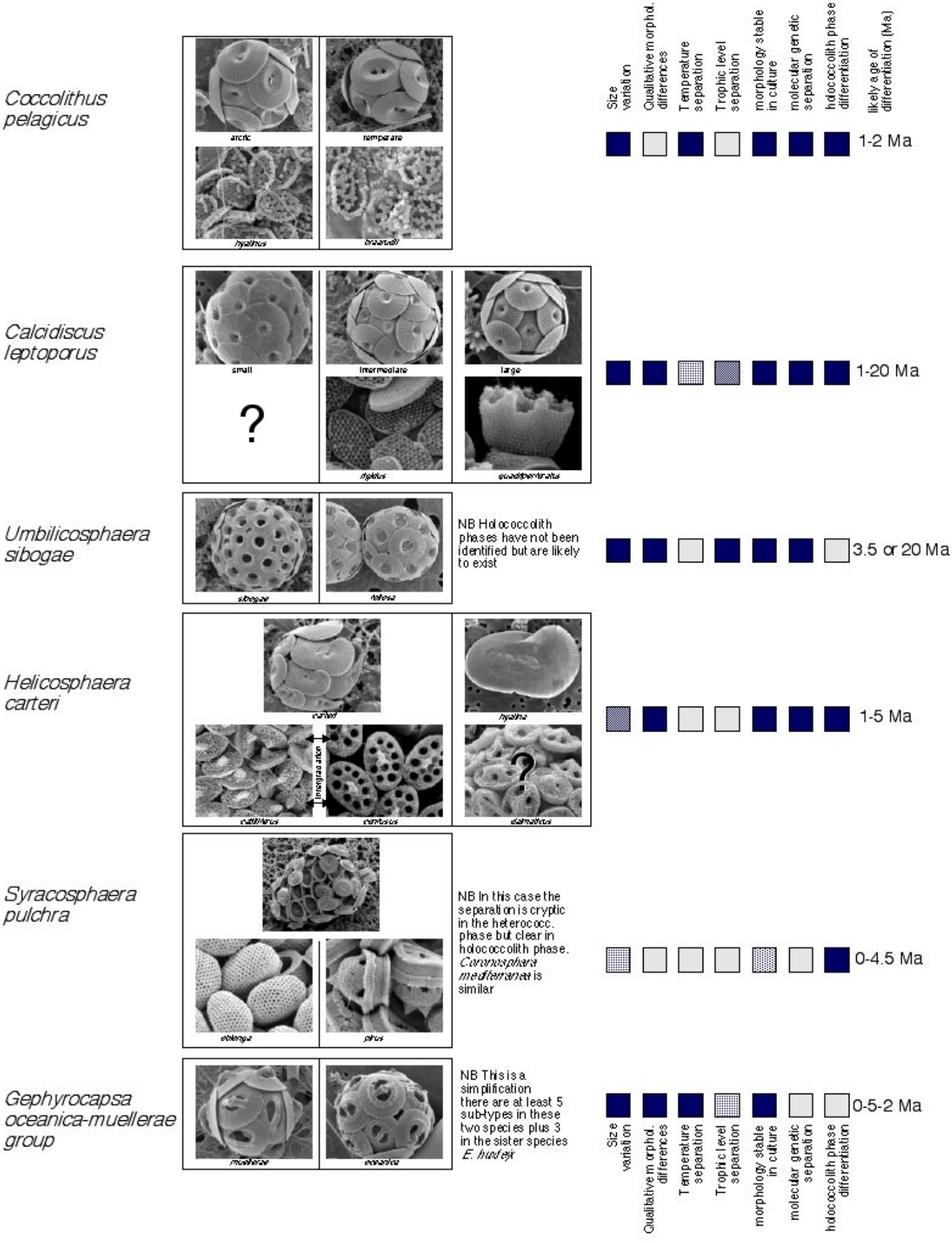
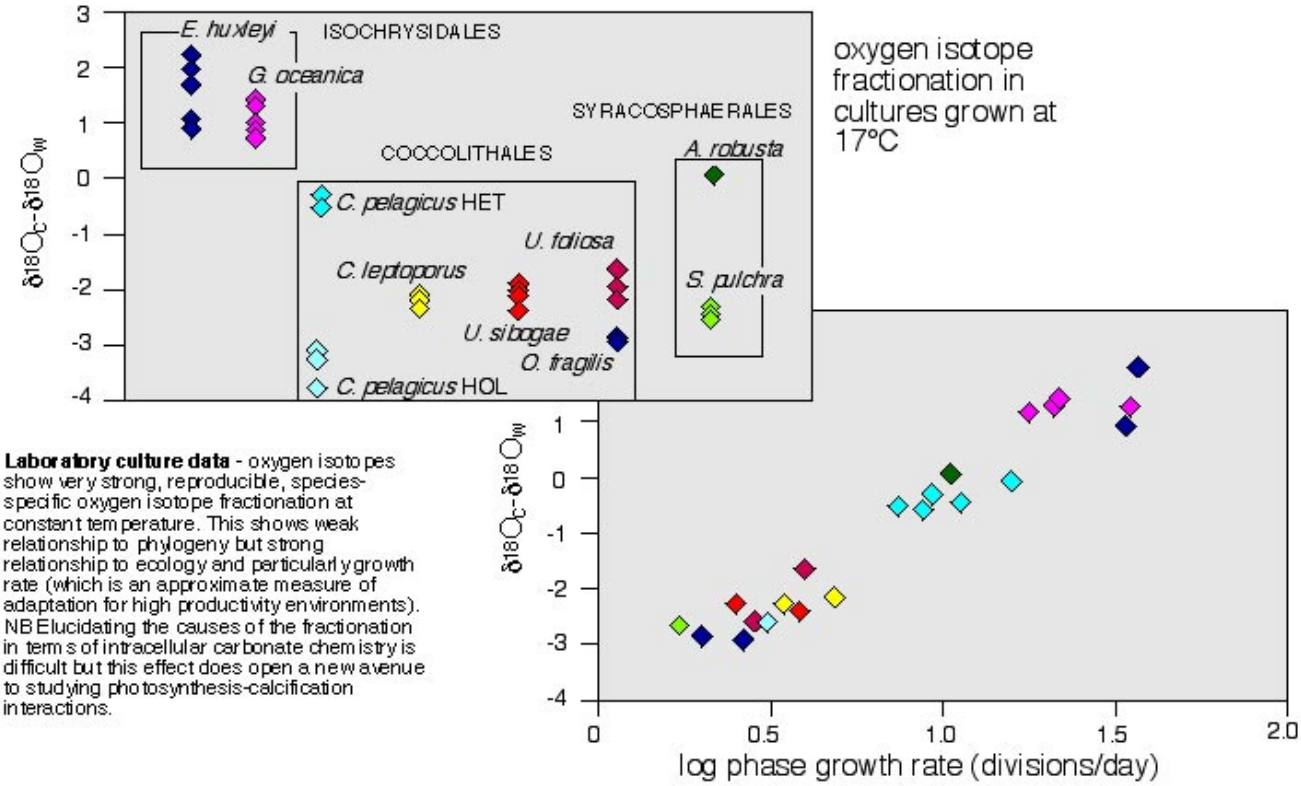


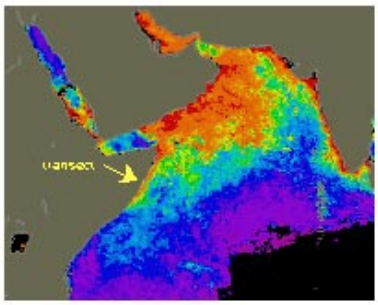
Fig. 5 Outline of intraspecific variation in the CODENET taxa

NB In the illustrations heterococcolith phases are illustrated above the holococcolith phases. Boxes indicate which types of evidence are available to support the inferred differentiation. See text for sources.

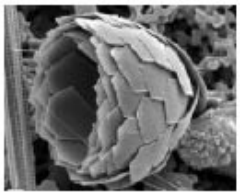


Laboratory culture data - oxygen isotopes show very strong, reproducible, species-specific oxygen isotope fractionation at constant temperature. This shows weak relationship to phylogeny but strong relationship to ecology and particularly growth rate (which is an approximate measure of adaptation for high productivity environments). NB Elucidating the causes of the fractionation in terms of intracellular carbonate chemistry is difficult but this effect does open a new avenue to studying photosynthesis-calcification interactions.

Field data - sediment samples from the Somalia upwelling system, with a strong onshore-offshore productivity gradient (see map, also Sr/Ca data and % obligate oligotrophic nannofossils). Total fine fraction carbonate (i.e. all nannofossils) shows only a weak offshore decline, less than would be predicted from temperature increase alone. Separating this sediment into fractions enriched in particular nannofossils yields oxygen isotope results that parallel the laboratory experiments, and show clearly for each species the predicted temperature related fall in values. The strong fractionation of the deep photic species *F. profunda* suggests that it is a high productivity species and the weak decline in total fine-fraction values offshore reflects the increased contribution of *F. profunda*.



CZCS Image for SW monsoon 1979, colours indicate surface water chlorophyll concentration



F. profunda - this work and many other studies has highlighted the key role of this species. Pat Quinn (ETHZ) has obtained funding for post-CODENET research on its diversity and ecology.

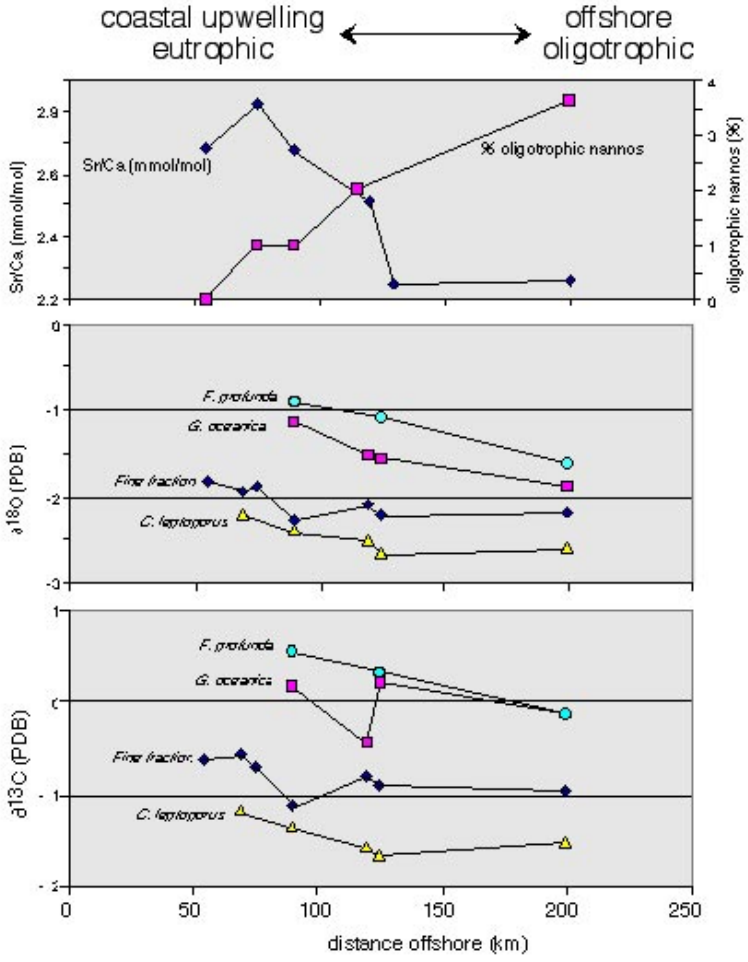
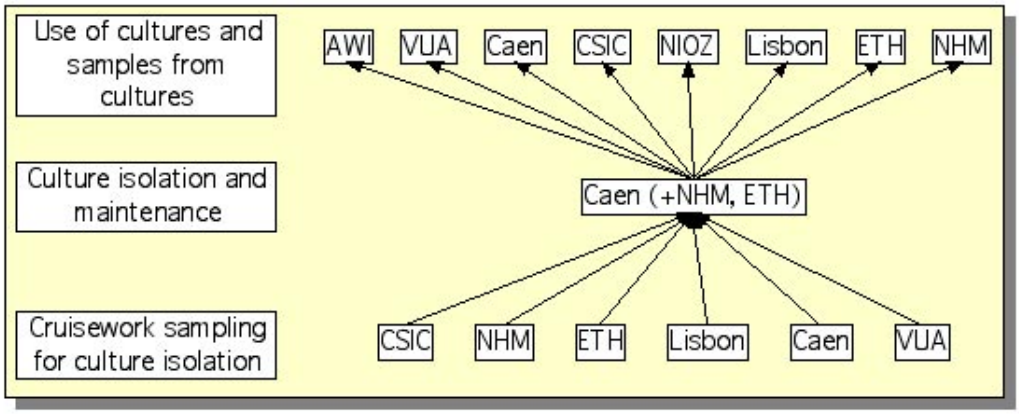
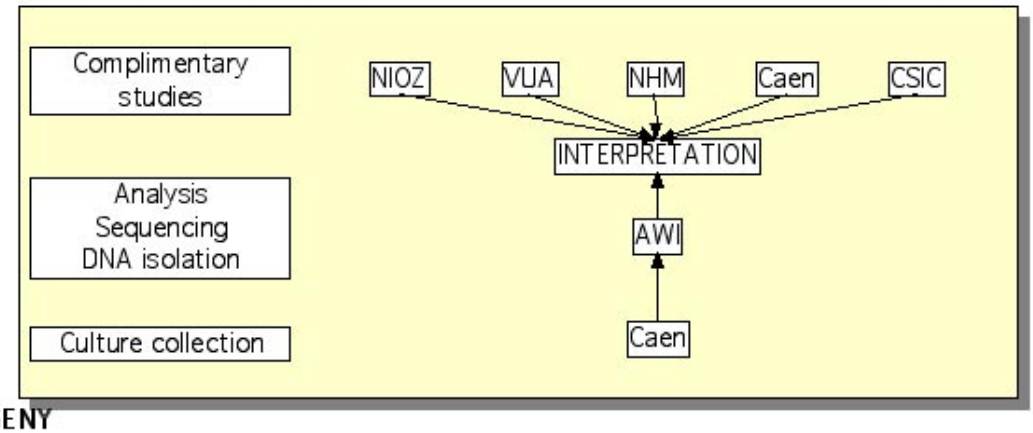


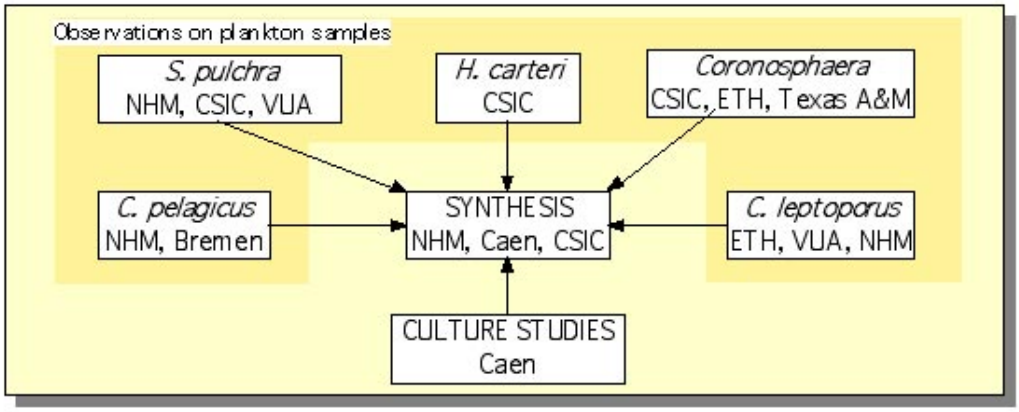
Fig. 6 - Oxygen isotope fractionation data from coccolithophores. (From Ziveri et al. in prep a,b)



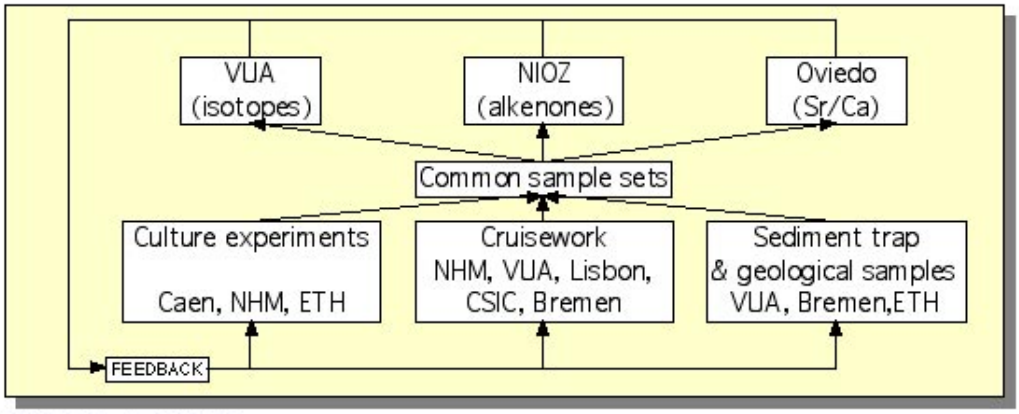
A.CULTURE ISOLATION



B. MOLECULAR PHYLOGENY



C. HOLOCOCCOLITH EVIDENCE FOR CRYPTIC SPECIATION



D. GEOCHEMICAL PALAEOPROXY STUDIES

Fig. 7 Patterns of Network Collaboration

CODENET

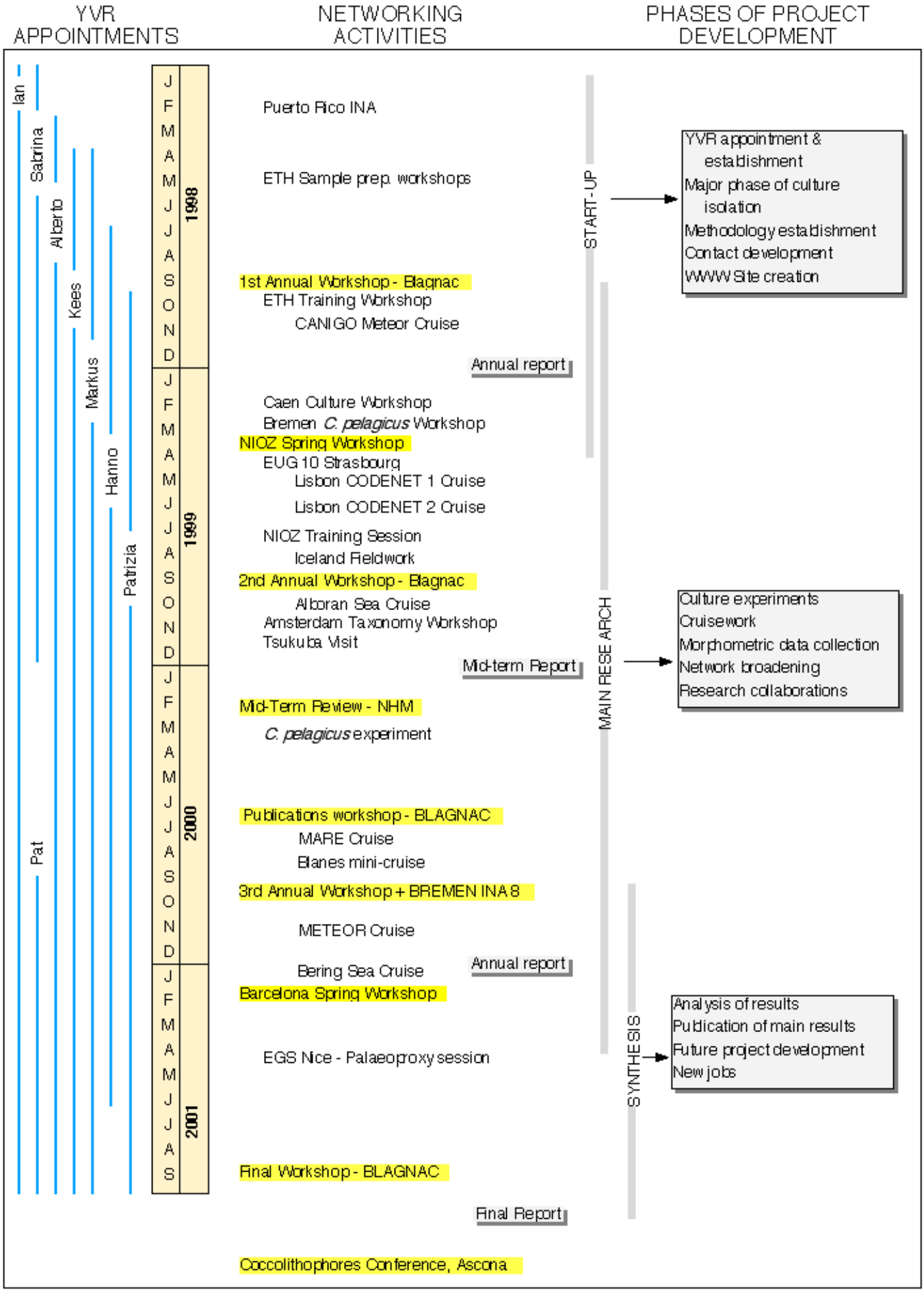


FIGURE 8 - OVERVIEW OF NETWORK DEVELOPMENT AND ACTIVITIES