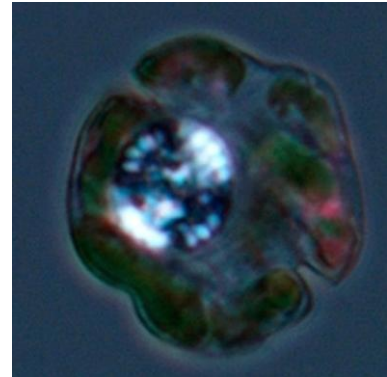


Karyo-Genomics in Nuclear Processing 1-14

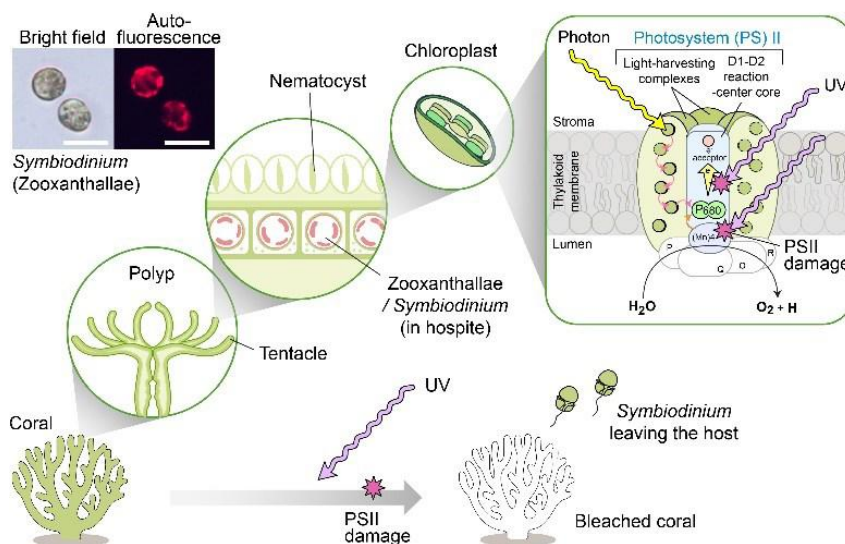
Phase transitions and self-assembly constitute major dynamic axes in nuclear transactions. Dinoflagellate quasi-condensed chromosomes (QCCs) represent the third major chromosome packaging mechanism, alongside bacterial nucleoid and eukaryotic nucleosomal packaging. QCCs lack canonical architectural nucleosomes and possess the lowest known chromosomal protein-to-DNA ratios among extant eukaryotes. Furthermore, they exhibit a substantial, non-random replacement of thymine with the fifth base, 5-hydroxymethyluracil. Their histone-like proteins, which belong to the linker histone/bacterial Hlp superfamily, organize DNA in a concentration-dependent manner, facilitating charge reversal and phase transitions within nucleic acid-protein assemblies. The DNA damage response is a common biomedical theme; probing these unique genome architectures integrates our understanding of genome integrity.

Keystone Concept: The nucleus functions as a compartmentalized unit tightly coupled with cytosolic commitment.



Birefringence of a dinoflagellate nucleus

Coral Biology, Coralites, and Minicircles 15-20



Zooxanthellae chloroplasts are distributed across subsurface networks, yet little is known about the vesicular transport pathways that likely connect the symbionts with their host cells. As in many mainstream dinoflagellates, peridinin-containing plastid genes have largely transferred to the nuclear genome; however, a small fraction (approximately 20 genes) remains encoded on "minicircles." A prominent example is the *psbA*

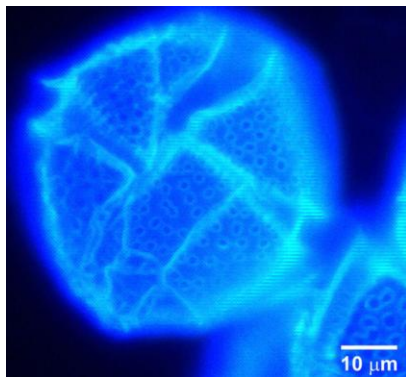
minicircle, which encodes a Photosystem II protein that undergoes dynamic changes during photoadaptation and in response to high UV irradiation causing photosystem damage. A steady supply of this protein is critical for the timely repair of damaged photosystems; failure in this process leads to photosynthetic dysfunction and initiates coral bleaching.

While multiple factors contribute to coral bleaching, neither partner can survive in nutrient-poor tropical waters without this symbiotic relationship. Zooxanthellae photosynthesize in shallow littoral environments at cell densities that could not be sustained by free-living dinoflagellates, essentially functioning as a restricted, host-contained algal bloom. The genomes of symbiotic

dinoflagellates are among the smallest in the group (1–1.5 Gb, discounting parasitic lineages), especially when compared to free-living dinoflagellates, which can possess genomes up to 200 Gb. This reduction is likely due to their specialization as coral symbionts, removing the selection pressure to maintain a massive genome. Furthermore, minicircles function not merely as passive plastid genomes, but as active, transcriptionally and translationally regulated extrachromosomal DNA:RNA hybrids.

Coral biology has been significantly advanced by recent successes in cell culture. We are actively investigating the calcareous dinoflagellate *Thoracosphaera heimii*. With a cell size of just 10 μm entirely covered in a carbonate shell, it possesses the highest known carbonate content per cell. We have mastered the induction of its carbonate shedding and re-synthesis, offering insights into the bio-efficiency of HCO_3^- sequestration, transfer, accumulation, and amphiesmal deposition. Because no *in vitro* models exist for coral cell lines, this system provides a vital comparative model for coralite carbonate epitaxy.

Cellulosic Thecal Plates and Polysaccharide Synthesis ²¹⁻²⁸



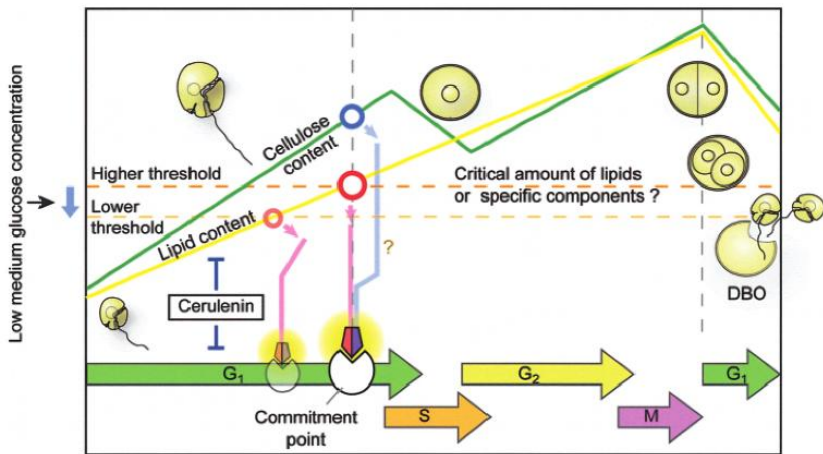
Fluorescence photomicrograph of CTPs

Cellulose is the most abundant biopolymer on Earth. Its hydrolysis and chemical modification serve as platform technologies across multiple industries, including wine, paper, biofuels, food, and textiles. *In vivo* cellulose biogenesis commonly involves substrate provision, membrane-dependent synthesis, and extracellular deposition. Thecate dinoflagellates are uniquely known for producing intricate, three-dimensional intracellular cellulosic thecal plates (CTPs). CTPs are deposited in precise arrangements (defining their taxonomic thecal formula) and are composed of ultra-fine fibers that exhibit the hardness of wood.

We are investigating the molecular biology of CTP biogenesis and its biotechnological applications. Because dinoflagellates are major agents of algal blooms and significant producers of carbon-negative DMS/DMSP, CTPs represent a potential next-generation green source of cellulose. CTPs are localized within the cortical amphiesma, a dynamic structure continuously replaced during ecdysis. The interchange between the pellicular layer and the CTP-alveolar sac layers forms the structural basis of life-cycle remodeling.

Growth Quotient in Mother-Daughter Cell Transfer ²⁹⁻³⁸

The cellular membrane and cell wall are primary drivers of cellular growth, representing the physical margins of life, while membrane flexoelectricity is regarded as a fundamental signature of living systems. Nutrient abundance and deprivation represent two extremes of cellular status; perceiving these states drives major life-cycle transitions in unicellular organisms. In dinoflagellates, growth-



genome cycles figure prominently in the coral-zooxanthellae relationship, algal bloom proliferation rates, ecological niche adaptation, and global productivity.

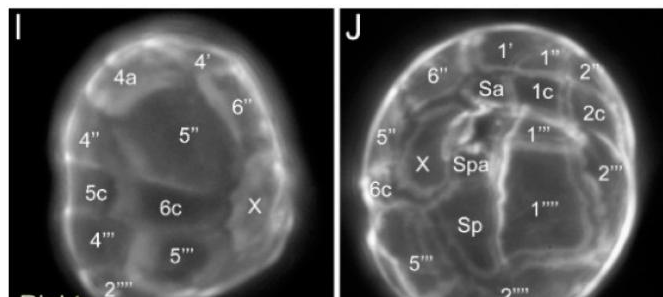
Our research focuses on *pmp3/mfp1*, a group of membrane proteolipids. In yeast, these localize to the plasma membrane and vacuoles, are associated with drug resistance, and regulate endocytosis alongside redox/GSH homeostasis. Plant homologues are associated with drought and environmental resistance, with numerous variants found across different tissues. We initially isolated *mfp1a* via subtraction cloning of the *mf2* mutant from wild-type G₁ cells, and our recent research demonstrates its coupling with membrane flexoelectricity.

Simultaneously, the paradigm surrounding melatonin's non-receptor functions is shifting, redefining it from strictly a circadian regulator to a molecule coupled with the redox-mitochondrial-energy axis. We isolated a mutant resistant to cell-cycle arrest induced by exogenous indoleamines, a significant finding given that photosynthetic dinoflagellates exhibit circadian melatonin fluctuations comparable to those of the mammalian pineal gland. We are currently preparing manuscripts detailing the role of *mfp1* homologues in redox-cellular growth coupling and general housekeeping functions related to protist membrane homeostasis.

Marine Biotechnology ³⁹⁻⁴⁶

Dinoflagellates are infamous for producing a vast repertoire of bioactive lipophilic compounds. These compounds frequently modulate membrane receptor readouts, causing major seafood poisoning syndromes. We propose harnessing the efficiency of biological carbonate sequestration and transfer for assisted carbonate deposition, integrated with the synthetic biology of oleaginous microalgae.

The heterotrophic dinoflagellate *Cryptothecodinium cohnii* serves as a major model for cell biology and is a significant industrial producer of docosahexaenoic acid (DHA), a key nutraceutical and pharmaceutical additive. Despite its biotechnological significance, including the use of various strains for DHA supplementation in infant formulas, the family *Cryptothecodiniaceae* remains incompletely described. This is partly due to their degenerative thecal plates and a lack of morphological descriptions correlated with specific ribotypes across many taxa. We have isolated a series of novel species, notably describing



Cryptothecodinium croucherii

Crypthecodinium croucherii sp. nov. (Kwok, Law, and Wong). This species exhibits distinct genome sizes, ribotypes, and amplified fragment length polymorphism (AFLP) profiles when compared to *C. cohnii*.

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