2. CALCIUM-BASED BIOMINERALS IN ASCIDIANS AND MOLLUSCS

2.1. Calcium-based Biominerals

Calcium carbonate is a calcium-based biomineral that is used to make the spicules of ascidians and the shells of molluscs. There are six calcium carbonate minerals with the same principal composition but different structure: calcite, aragonite, vaterite, calcium carbonate monohydrate, calcium carbonate hexahydrate, and amorphous calcium carbonate.

Calcium carbonate, in its three non-hydrated crystalline polymorphs (calcite, aragonite and vaterite), represents one of the most important inorganic materials with respect to the biomineralization processes in organisms. Of the three modifications, calcite is thermodynamically the most stable one, followed by aragonite and then vaterite, which is the least stable one. However, only the two most thermodynamically stable structures, which are calcite and aragonite, are deposited extensively as biominerals (Table 1).

Calcium carbonate minerals have high lattice energies and low solubilities, and are therefore thermodynamically stable within biological environments. In general, the precipitation of calcium salts provides an effective means to control the Ca^{2+} ion concentration in biological fluids. This helps to maintain a steady – state condition corresponding to an intracellular calcium concentration of around 10^{-7} M (Mann, 2001).

Table 1. Calcium carbonate biominerals (Mann, 2001)

Mineral	Formula	Organism	Location	Function
Calcite	$CaCO_3$	Coccolithophores	Cell wall scales	Exoskeleton
		Foraminifera	Shell	Exoskeleton
		Trilobites	Eye lens	Optical imaging
		Molluscs	Shell	Exoskeleton
		Crustaceans	Crab cuticle	Mechanical strength
		Birds	Eggshells	Protection
		Mammals	Inner ear	Gravity receptor
Mg-calcite	$(Mg, Ca)CO_3$	Octocorals	Spicules	Mechanical strength
		Echinoderms	Shell/spines	Strength/protection
Aragonite	$CaCO_3$	Scleractinian corals	Cell wall	Exoskeleton
		Molluscs	Shell	Exoskeleton
		Gastropods	Love dart	Reproduction
		Cephalopods	Shell	Buoyancy device
		Fish	Head	Gravity receptor
Vaterite	$CaCO_3$	Gastropods	Shell	Exoskeleton
		Ascidians	Spicules	Protection
Amorphous	$CaCO_3 \cdot nH_2O$	Crustaceans	Crab cuticle	Mechanical strength
		Plants	Leaves	Calcium store

Table above shows that ascidians used these calcium-based biomineral for protection, while molluscs used these calcium-based biomineral to make their exoskeleton shell rigid.