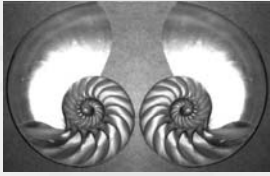
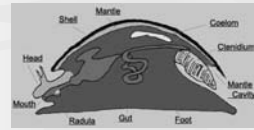


**Nacre:
the natural beauty of mother of pearl**



The Mantle: A Common Characteristic of Molluscs

All molluscs possess:
A fleshy foot, a radula (rasping organ-bivalves have lost this feature), a digestive system, and gills (labelled "ctenidium" here)...
...but most importantly, for purposes of this lecture, a mantle (a fleshy membrane of tissue that surrounds the visceral mass).



Generic mollusc
(showing features common to all molluscs)

Mother Of Pearl

Mother of pearl is a common term for lustrous, iridescent material forming the inner surface of (molluscan) seashells.



Turban shell Abalone gastropods

The material comprising mother of pearl is called *nacre*.

Nacre production is widespread among molluscs, the invertebrate group (Phylum) that includes the bivalves (clams, mussels and oysters), the gastropods (snails) and cephalopods (primarily *Nautilus* and extinct ammonites)



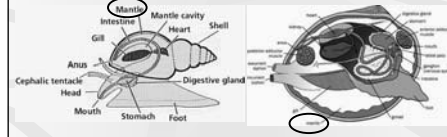
Pearl oyster Freshwater clam bivalves



Nautilus cephalopod

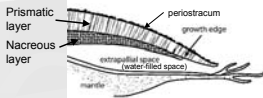
The Mantle: The Key to Shell Construction

The mantle not only serves to protect delicate internal tissues, but is also responsible for shell secretion (in forms that have a shell). Calcium in molluscan blood reacts with dissolved carbon dioxide to result in the precipitation of solid calcium carbonate used in the construction of the various layers of the shell.



Function of the Mantle

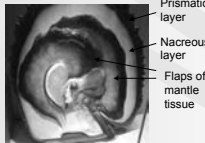
At the leading edge of growth, the mantle secretes prisms of calcium carbonate (aragonite or calcite).



Cross section of pearl oyster shell

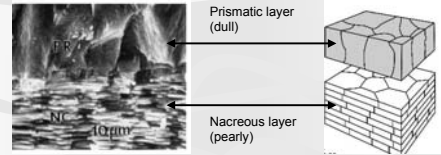
The mantle then covers the prismatic layer with tablets of aragonite nacre (this is the mother of pearl layer observed on the shell interior).

Note that when shell secretion is not taking place, the mantle separates from the shell.



Interior of pearl oyster shell

Internal Structure of Shell



The prismatic and nacreous layers have different optical properties due to differences in crystal habit. The prismatic layer (composed mostly of blocky prisms of calcite or aragonite) tends to be weakly translucent to opaque.

The nacreous layer (composed mostly of plate-like tablets of aragonite), is shiny, translucent and often very colourful.

The smooth fine laminae surface of the nacreous layer allows mantle tissue to slide against the shell without being damaged.

A Closer Look at Nacre

Nacre is largely, but not entirely, composed of aragonite crystals; films of organic matter (specifically as the substance conchiolin) and water are also present within the nacreous layer.

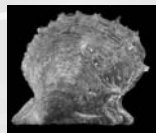
The general composition of mother of pearl (and pearls) is as follows:

Aragonite (82-86 %)
Tablets of aragonite form the framework of nacre

Conchiolin (10-14 %)
This is a complex organic substance (C₂₃H₃₄N₂O₁₁) made of polysaccharides (complex sugars) and protein fibres.

Water (2-4 %)
Most of this water occurs in the conchiolin layers.

On top of the prismatic layer, an organic material called the periostracum is deposited (providing protection from dissolution and mechanical damage and, to some extent, camouflage).



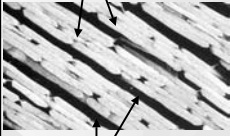
Shell exterior (covered by periostracum)

The drab exterior of the pearl oyster (and other molluscs) conceals the beauty within. Don't judge a book by its cover!



Structure of Nacre: Cross sectional view

Sheets of aragonite tablets held together by conchiolin



This is an edgewise (cross sectional—shell cut across its length or width) view of nacre as observed under SEM (conchiolin has been dissolved in this sample)

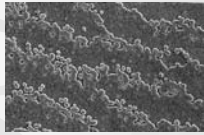
Tablets of aragonite are glued to adjacent tablets with conchiolin.

Individual tablets can form thicker sheets, with intervening sheets of conchiolin.

Thicker sheets of conchiolin between sheets of aragonite tablets

Structure of Nacre: Plan view

This is an surface (plan) view of nacre as observed under SEM.



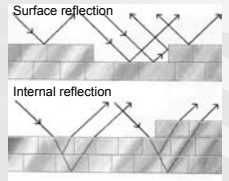
In this image, the hexagonal shape of the aragonite tablets can be observed.

Note that the aragonite sheets do not uniformly cover the surface; they partially overlap one another, forming a step-like pattern.

Lustre

The quality of lustre in nacre is a function of two major things:

- Quality of surface reflection: Aragonite tablets behave as mirrors. The ability of the surface layer to reflect light determines the brilliance of the lustre.
- Quality and depth of internal reflection: Aragonite tablets also behave like windows – they transmit some of the incoming light. Light can be reflected off internal crystal surfaces, giving nacre a warm internal glow. Generally, the thicker the nacre is, the more reflective (shiny) it will tend to be as a result.

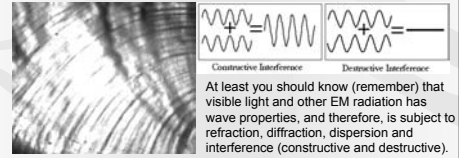


Orient

The iridescent play of colours in nacre is called *orient*.

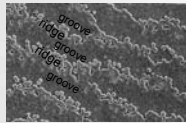
The intensity of orient is dependent on similar factors as those that produce lustre: the reflection of light off surfaces and the behaviour of light within the nacre (internal reflection, diffraction, dispersion).

Details of these concepts are impossible to explain without the use of mathematical equations, so we'll just stick to the basic ideas!



Orient: Influence of Surface Relief

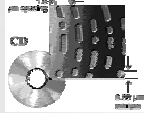
One contributor to orient is the splitting of light waves into individual colours of the spectrum due to the regular arrangement of layered bands of grooves and ridges on a surface.



grooves and ridges on nacre

At certain angles of viewing, waves of certain colours (each reflected at a specific angle) are reinforced, making those colours more brilliant. This is called constructive interference.

The same principle applies to iridescence of the surface of a compact disc which is characterized by alternating lines of pits and ridges (lands). These produce what is known as a diffraction grating.



Uses of Nacre

Nacre has many applications in raw form.

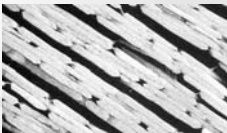
A popular practice among some shell collectors is to remove the outer prismatic layer of a shell to reveal the more attractive nacreous layer.

It is also a popular material for jewelry, inlays in musical instruments, and various other ornamental applications.

Nacre has also been widely used for making buttons.



Orient: Influence of Refraction and Reflection



Individual crystals of aragonite can also act as tiny prisms, refracting light and dispersing it into the colours of the rainbow.



This effect is further enhanced by the interaction of outgoing light waves (refraction and dispersion going in and out) that have bounced off multiple crystal surfaces within the sheets of nacre (constructive interference).

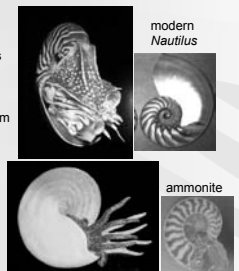
Ammolite: Fossil Nacre

A gemstone that has only recently entered the market is ammolite.

Ammolite, fossil ammonite nacre, is rather rare because under normal preservational circumstances, aragonite either dissolves or is recrystallized to the more stable form of calcium carbonate, calcite.

As you will recall, ammonites are extinct relatives of the Nautilus, squids, octopuses and cuttlefishes.

Like Nautilus, ammonites had a chambered shell filled with gas and liquid for buoyancy regulation.



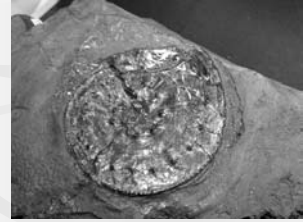
Orient in Ammolite

Ammonites with exceptionally well preserved nacre occur in the Late Cretaceous Bearpaw Shale, south of Lethbridge Alberta (about 70 million years old).

For reasons still unanswered, the play of colours in ammonite nacre from the Bearpaw Shale have been greatly enhanced in intensity due to constructive interference (this might have to do with slight deformation of aragonite crystals within the nacreous layers) or the presence of impurities.



Go figure that one of the most attractive gemstones comes from a squid-like animal ! And it's Canadian.



Orient in Ammolite

Ammolite is somewhat difficult to work with because it readily splits apart along planes between aragonite sheets (low tenacity)

It is also quite soft and is prone to scratching (low hardness).

The ammolite must therefore be processed in a different way than most gemstones.

Sheets of ammolite are ground and polished, attached to a backing (either pieces of the original matrix or harder material), and capped with a cabochon of quartz or spinel (required to protect it from scratching or spitting).



END OF LECTURE