CHEMICAL DETERGENTS USED IN THE DECELLULARIZATION OF HEART VALVES

What are Detergents?
Chemical detergents, also known as surfactants, are defined by their ability to break down organic material. Surfactants are comprised of a hydrophilic head and a hydrophobic tail. This formation allows the surfactant molecules to surround and solubilize organic material.

The figure above portrays a surfactant’s orientation in the presence of organic material such as oil.

- This unique design allows for organic materials to be washed away with water. Common applications of surfactants include hand soaps and laundry detergents. However, surfactants also have applications in the medical field such as organ decellularization.
- When in contact with mammalian tissue, chemical detergents can:
  - Break down cellular material
  - Break down proteins holding cellular material together
  - Solubilize cytoplasmic and nuclear cellular membranes
  - Break down lipid-lipid, lipid-protein, and protein-protein interactions

Types of Detergents
Detergents can be classified as either ionic or non-ionic, based on how they dissociate when in contact with water.

Ionic
Ionic detergents are classified by their charge when in water. They can be either anionic or cationic depending on the sign of their charge. These detergents are comprised of a hydrocarbon chain attached to a soluble, charged molecule. When in solution with proteins, the polar heads of the ionic detergent surround the proteins, orienting the hydrophobic tail towards the protein, and unfolding the tertiary structure of the protein. Some ionic detergents include sodium dodecyl sulfate (SDS) and sodium deoxycholate.

SDS (Sodium Dodecyl Sulfate)
The charged molecule in SDS is able to surround proteins and disrupt their hydrophobic effect. The hydrocarbon tail unfolds the protein structure and allows for solubilization.

The figure above shows the effect of SDS on protein tertiary structure unfolding.

- Sodium Deoxycholate
Sodium deoxycholate tends to act more like a non-ionic detergent, but its polar properties classify it as ionic. Sodium deoxycholate is able to bind to proteins without unfolding a protein’s tertiary structure.

- Triton X-100
An example of a non-ionic detergent is Triton X-100. Triton X-100 is one of the most commonly used non-ionic detergent due to its ability to increase the permeability of a cell membrane. However, above the CMC, Triton X-100 often causes cellular structure disintegration which is an unwanted effect for applications such as decellularization.

Decellularization
Decellularization is the removal of cellular material from the extracellular matrix of an organ. The extracellular matrix (ECM) is a biological substructure comprised of structural proteins which aids in organ support and function. When the ECM is used as a conduit for new cell growth, it is known as an organ scaffold.

Chemical detergents can be used in the process of decellularization to remove cellular material from the ECM. Due to the varying strengths and abilities of chemical detergents, they are most commonly used together in smaller quantities rather than being used individually.

The development of organ scaffolds through decellularization allows for the creation of implantable organs to replace nonfunctioning human organs. While it is very difficult to decellularize entire organs, smaller pieces of organs can be successfully decellularized using detergents.

Heart Valves
One organ piece that has been successfully decellularized and implanted in humans is the heart valve. Chemically decellularized heart valves have proven to be safer when used as replacement organs. Mechanical or bioprosthetic heart valves often become clogged or calcify over time.

Decellularized heart valves such as the one to the right can be recellularized using host cells and implanted in a human to replace malfunctioning heart valves.

Importance of Decellularized Heart Valves
The development of working heart valve replacements aids in the curing of congenital and acquired heart defects. Since heart disease is the leading cause of death in America, the ability to fix many of these problems with replacement heart valves proves the extreme importance of such a technological development like chemical detergent decellularization.