Article 12 - Mechanosensitive self-replication driven by self-organization

Carnall, J. M. A.; Waudby, C. A.; Belenguer, A. M.; Stuart, M. C. A.; Peyralans, J. J.-P. .; Otto, S. Mechanosensitive Self-Replication Driven by Self-Organization. Science 2010, 327 (5972), 1502–1506. https://doi.org/10.1126/science.1182767.

Figure 1:

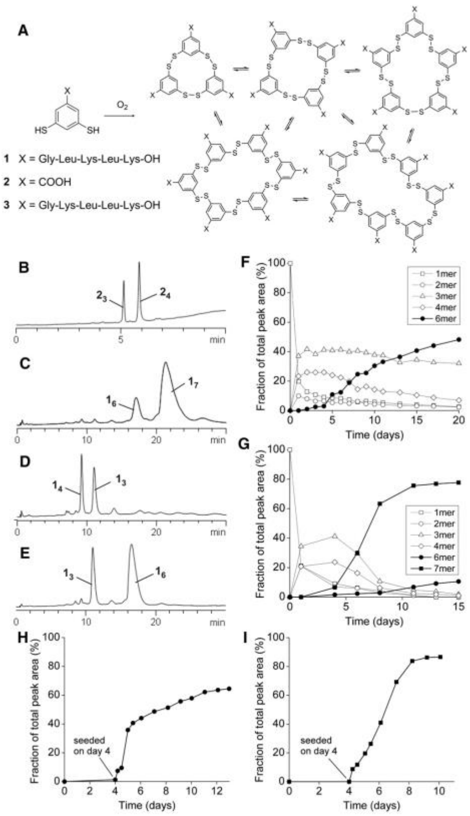


Figure 1 illustrates the process of forming larger ring-shaped molecules (macrocycles) from a small library of building blocks under various conditions. Panel (A) shows a schematic of the dynamic combinatorial library made from dithiol building blocks. Panels (B) through (E) display the results of high-performance liquid chromatography (HPLC) analyses, highlighting how different agitation methods and durations influence the types of products formed. Specifically, stirring and shaking the solution at various speeds and for different lengths of time result in distinct product distributions. Panels (F) and (G) track the evolution of the products over time, showing how shaking or stirring affects the growth of specific macrocycles. Finally, panels (H) and (I) demonstrate how adding a small amount of pre-formed macrocycles (seeds) accelerates the growth of cyclic hexamers and heptamers, depending on the conditions applied. Together, these results emphasize the role of mechanical forces and seeding in driving the self-organization and replication of macrocycles.

<u>Synopsis:</u>

The 2010 study Mechanosensitive Self-Replication Driven by Self-Organization by James M.A. Carnall, Christopher A. Waudby, Ana M. Belenguer, and M.C. Stuart delves into how certain molecules can replicate themselves in response to mechanical forces, mimicking the self-replicating processes seen in living organisms. The research is a significant contribution to the field of synthetic biology and materials science, as it explores how self-replication can be driven not just by chemical reactions, but by physical forces as well. This could open new possibilities for creating systems that can adapt, repair, and replicate themselves in response to environmental stimuli.

The researchers focused on a specific set of molecules known as peptide-derived macrocycles, which are large, ring-shaped molecules made up of amino acids. These molecules were part of a dynamic combinatorial library, a collection of molecules that can change their structure based on their environment. In this case, the macrocycles were competing for a shared feedstock—a common substance from which they could form. This competition led to the emergence of self-replicating molecules through a process driven by self-organization. In essence, the macrocycles spontaneously organized themselves into structures that replicated in response to mechanical forces applied to them.

The process begins with the formation of the peptide-derived macrocycles from the feedstock, which serves as the building block for the molecules. Once the macrocycles are formed, they begin to compete with each other for more feedstock. This competition is key, as it drives the emergence of the most efficient replicating macrocycles. Once a macrocycle has formed, it can replicate itself, a process that is driven by mechanical forces such as pressure or shear stress. These forces play a crucial role in triggering the replication, making the process "mechanosensitive."

A key figure from the article helps to illustrate this process visually. The figure first shows the formation of the macrocycles from the feedstock. Then, it depicts the competition between different macrocycles as they vie for the feedstock. Finally, the figure illustrates the replication process, showing how the macrocycles replicate in response to mechanical forces. This visual representation helps to convey the self-replicating nature of the macrocycles and their response to mechanical stimuli.

The study's findings have important implications for the development of self-replicating systems in synthetic biology. The ability to replicate molecules in response to mechanical forces opens the door to creating artificial systems that mimic the self-replication seen in biological systems. This could have applications in creating materials that can repair themselves when damaged or self-assemble in response to environmental changes. For example, materials used in construction, electronics, or medical devices could potentially "heal" themselves when subjected to mechanical stress or damage, reducing the need for external intervention.

The research also offers insights into the fundamental principles of self-organization in chemistry and biology. By understanding how molecular systems can organize and replicate in response to external forces, scientists can design new materials and devices that have the ability to adapt and respond to their surroundings. This could lead to advancements in fields like nanotechnology, where materials with the ability to self-replicate or self-assemble are highly sought after.

In summary, Carnall and colleagues' research provides valuable insights into the mechanisms of self-replication driven by self-organization. By demonstrating that mechanical forces can trigger the replication of peptide-derived macrocycles, the study opens up exciting new avenues for synthetic biology and materials science. This work not only deepens our understanding of molecular self-replication, but it also paves the way for developing new materials and systems that can adapt, repair, and replicate themselves in response to environmental stimuli. The potential applications of this research are vast, from self-healing materials to more responsive and adaptive technologies.