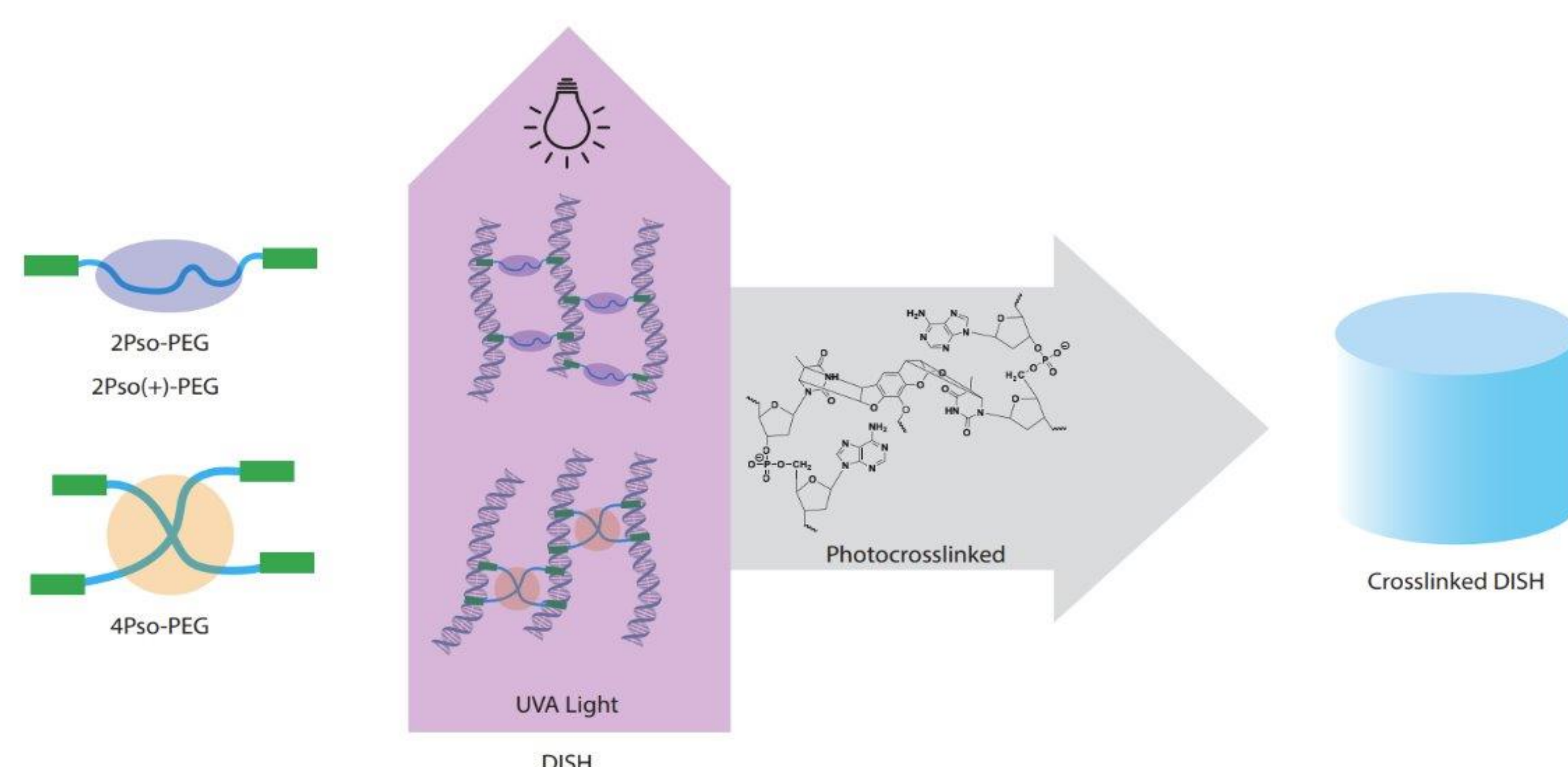
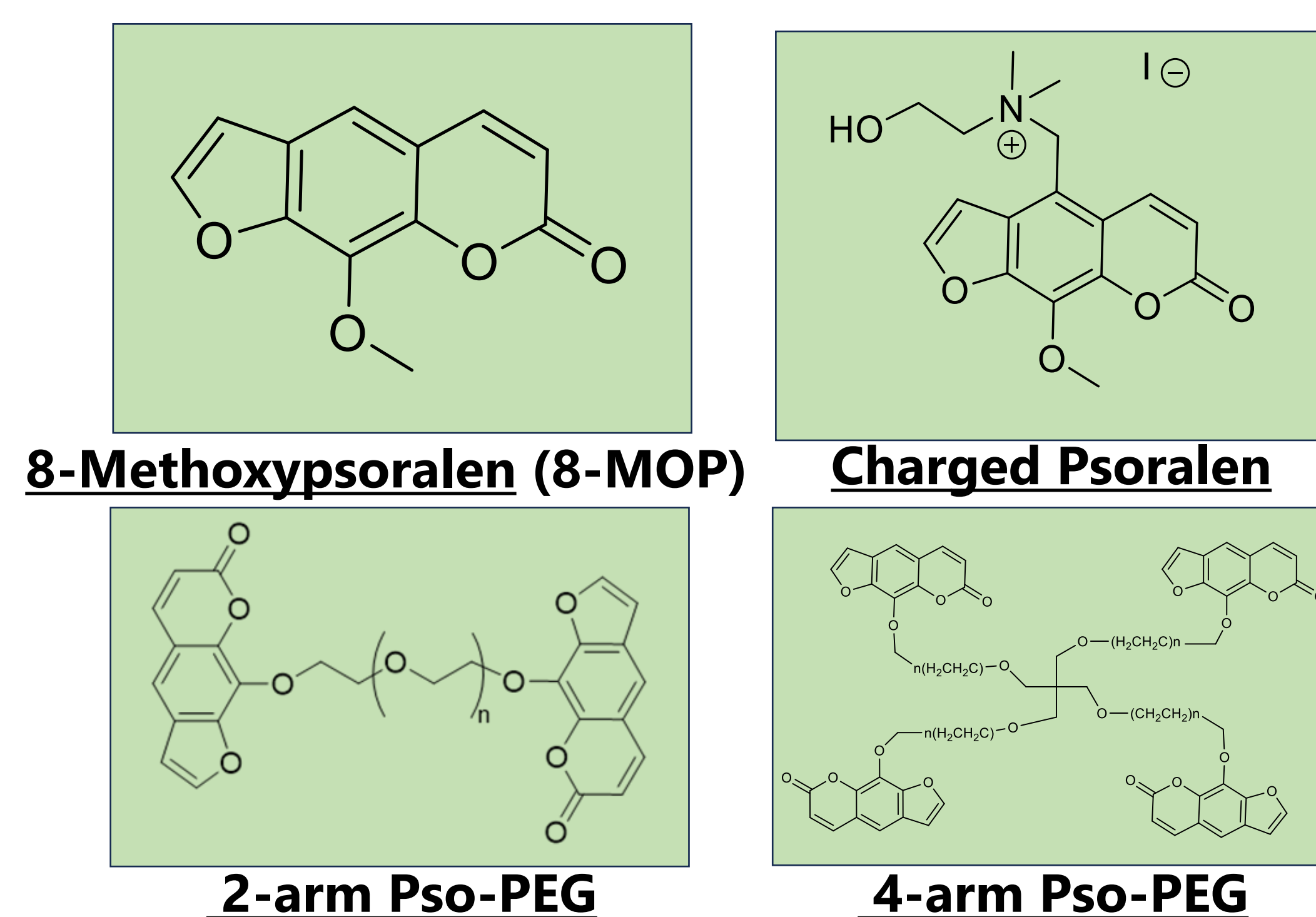


## Utilizing Photo Crosslinking Abilities of Psoralen for 3D Printing



**Figure 1.** Variation of the 2-arm and 4-arm Pso-PEG and how the UV activation works when making a 3D design.

In most experiments, when planning on 3D printing, there is a gelatin-like material used. But in this project the material used is DNA. This is because it is already a material found inside us. So, when moving on to the clinical trials it is more widely accepted. If we can successfully 3D print with our DNA hydrogel it would help prove the functionality of the gel, the control of cells and most importantly the extracellular matrix. The main goal of this experiment is to be able to implant a familiar complex but also be able to manipulate what the complex can do. Intercalation is another key factor in this project. It is the reversible inclusion or insertion of a molecule (or ion) into layered materials with layered structures. In this project, we are utilizing Psoralen for its ability to interact with DNA via intercalation, as well as its photo cross-linking abilities. This has been utilized in the treatment of skin conditions such as Psoriasis, Vitiligo, and Skin nodules of cutaneous T-cell lymphoma. The UV irradiation forms covalent, water-stable cross-links, making them ideal for hydrogel formation. A key function of cross-linking with psoralen is the retention of the DNAs double-stranded structure allowing for a stronger, uniform network. DNA hydrogels are known to have sheer-thinning behavior making these an attractive option for 3D printing applications. For this project, we hoped to explore the material properties of Psoralen as a cross-linker when attached to both 2-arm and 4-arm polyethylene glycol (PEG) (2-arm Pso-PEG and 4-arm Pso-PEG)

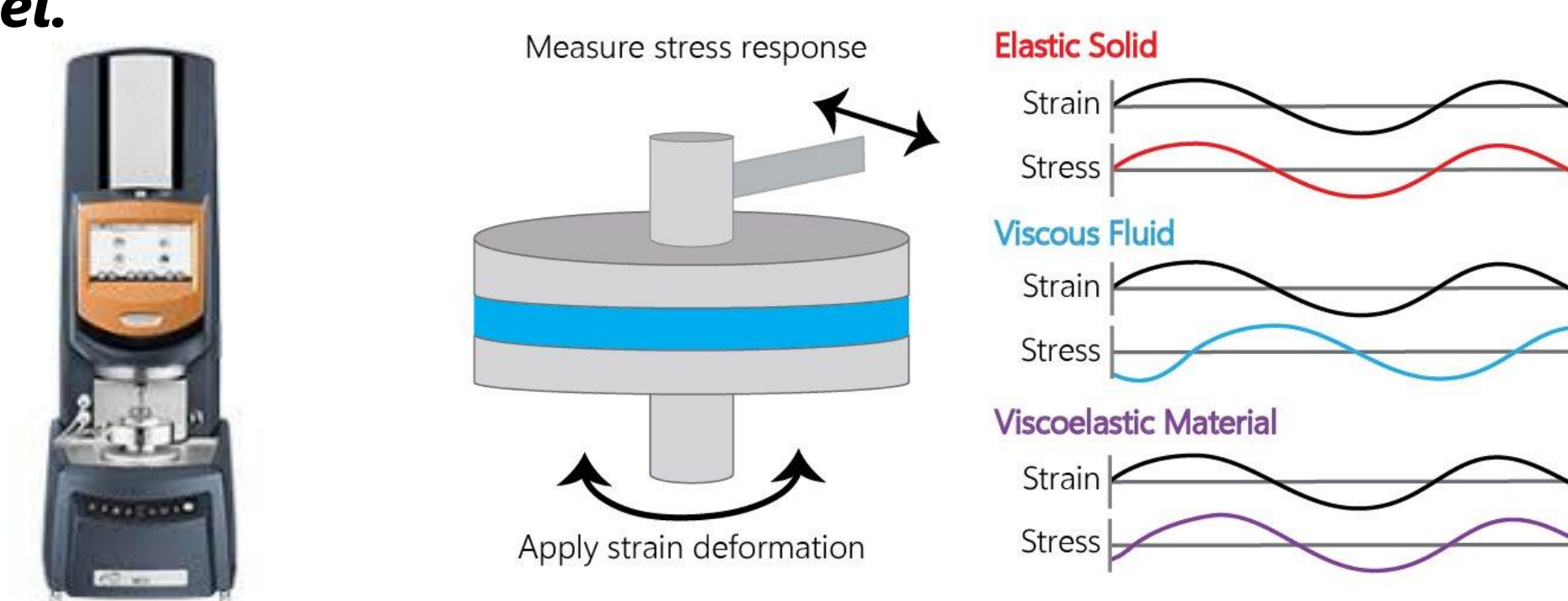


**Figure 2.** 8-MOP is the Psoralen of interest in this study and has been attached to both 2-arm and 4-arm PEGs. We are also interested in the formation of a charged psoralen to explore the additional interaction with DNA's negatively charged phosphate backbone.

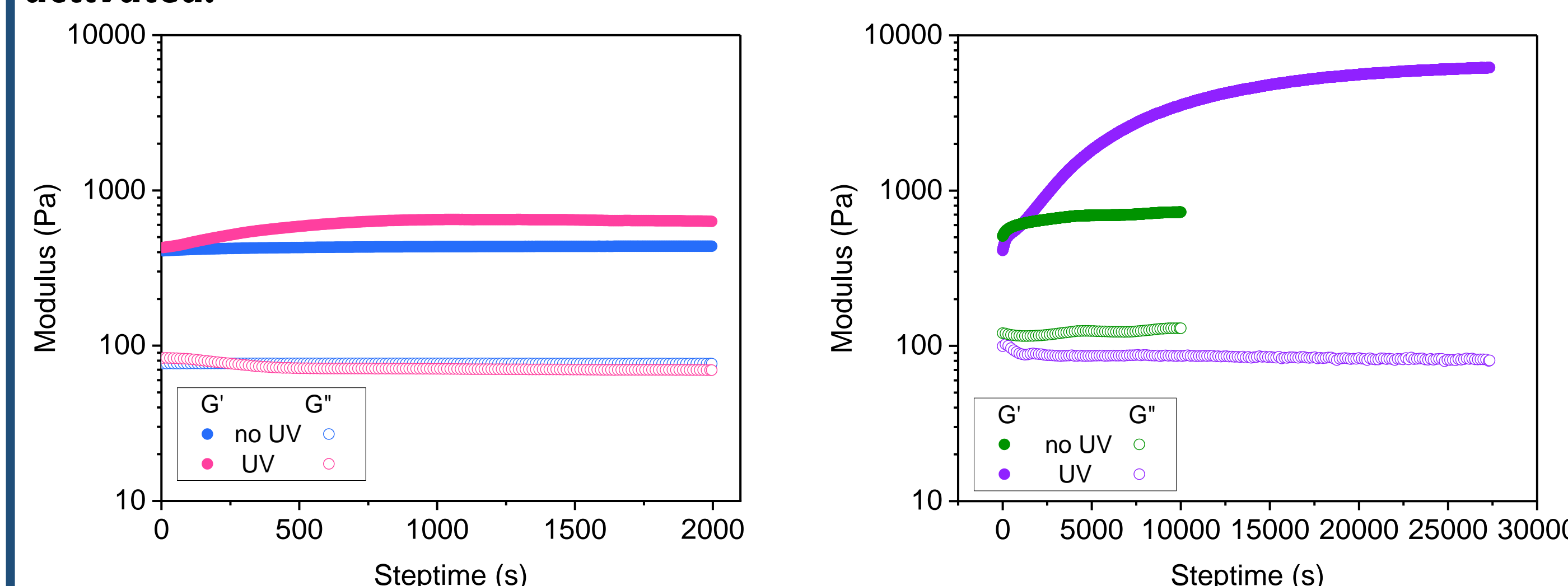
## Increasing stiffness of hydrogels with UV activation

Rheology is the study of matter deformation resulting from applying force. We utilized an oscillatory time sweep to determine the stiffness of both 2-arm and 4-arm Pso-PEG when being UV-activated. As the 4-arm Pso-PEG had a significant change in modulus when photo cross-linked, we chose to focus on this for 3D printing.

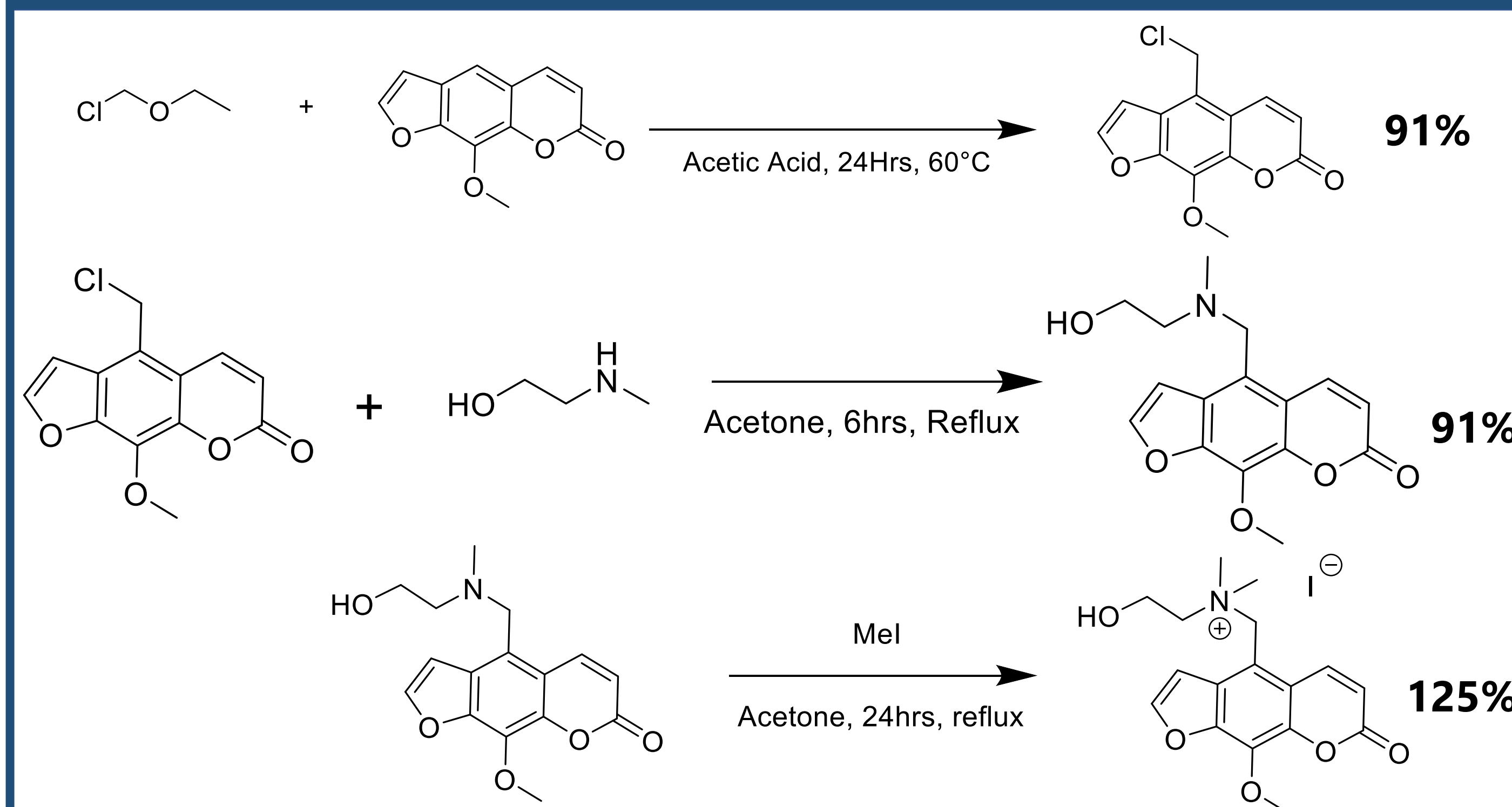
**Figure 4.** The comparison of the amount of stress applied to the amount of strain applied to the hydrogel.



**Figure 3.** Time sweep comparisons of 2-arm and 4-arm Pso-PEG when being UV-activated.



## Synthesis of charged Psoralen

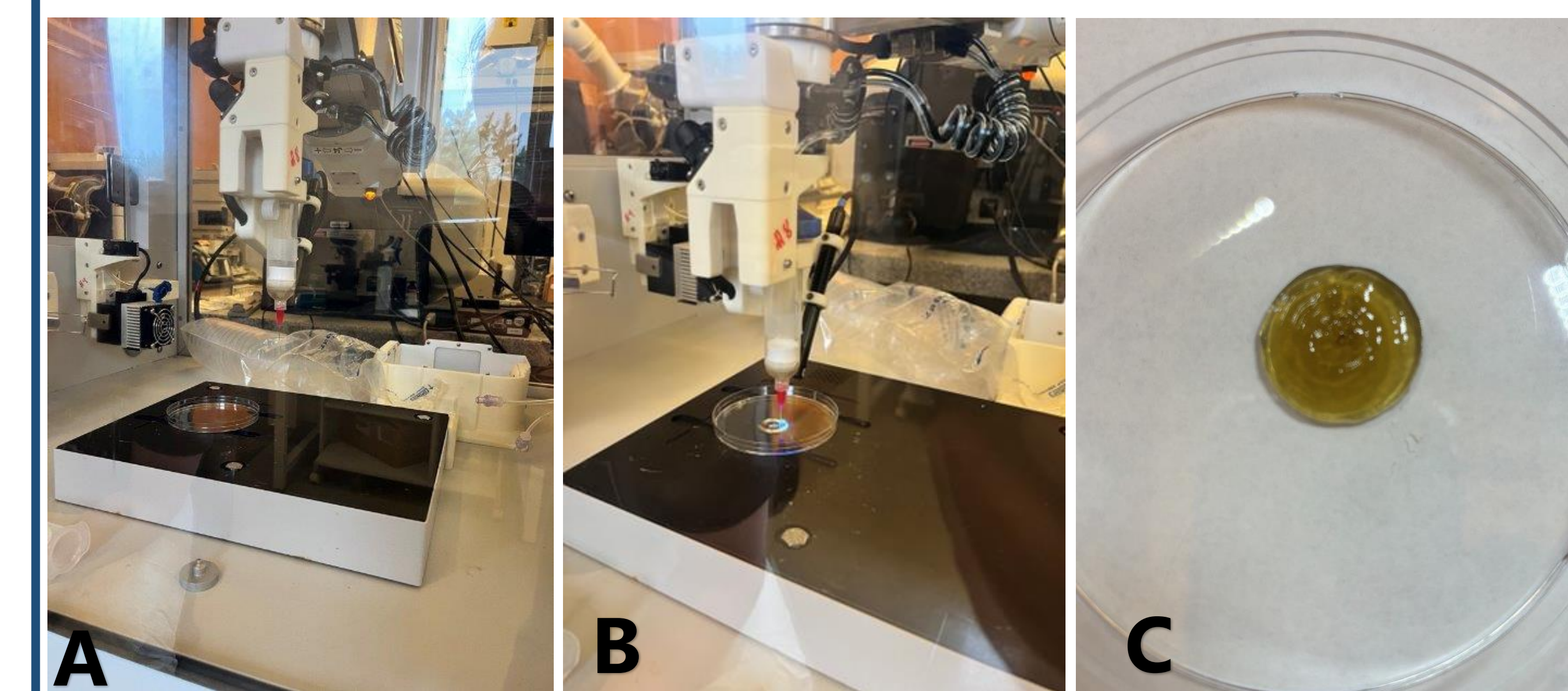


The first step of the charged psoralen synthesis is the addition of Chloromethyl ethyl ether. The next step is the addition of the 2-(Methylamino)ethanol; this step shows that the chlorine group leaves and is replaced by the new attachment of that 2-(Methylamino)ethanol. The final step is adding the Methylene Iodine. Which helps give a positive charge to that nitrogen and leaves the charged psoralen in the end. We are hoping to lower the percent yield in the final (charge psoralen) step and optimize the attachment of the charged psoralen to PEG<sub>2k</sub>.

## 3D Printing of 4 Arm Pso-PEG

The first step in 3D printing is loading the gel into the syringe. After we tested the ideal pressure needed to push the gel out of the needle. The gel needed to be pushed through a small needle, so we had to keep adjusting the amount of pressure applied to the gel. In the end was 85 psi applied to the gel. Once this step was completed and the printing was calibrated the printing could begin. While it's printing there is a UV light that is being applied to the gel. In Figure 8 the UV photo cross-linking properties are occurring. When the gel is being released from the needle it must be fluid enough to be released but with the UV activation, it is curing under that light. That way it can hold its structure and create that 3D design. Figure 6 C is our DNA hydrogel this gel is the second successful gel printed and the first one holding its structure. we created a circle with ridged circles within. We are optimizing the process to print out a larger design.

**Figure 6.** a) The arm of the 3D printer b) The UV activation of the gel c) Hydrogel with a 2.5 wt% DNA and 3mM crosslinker.



## Future Work

We are working on the attachment of the charged Psoralen to PEG<sub>2k</sub> and will continue to brainstorm new reaction conditions to help this attachment. Also, continue running more hydrogels on the rheometer to understand the correct viscosity needed. Lastly, make a new 3D design that will work better with the gel.

## Acknowledgments

Thank you to the UNH chemistry department, Wynter Paiva, Matthew Currier, Tran Truong, Patrick Strobel, Lola Fadairo, Zahraa Albeshir, Noelle Honan, Sam Ashooh, April Weeks, Lauren Barnes, and Dylan Sager. NH BioMade is funded by NSF Award #IIA 1757371 administered by NH EPSCoR at UNH

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