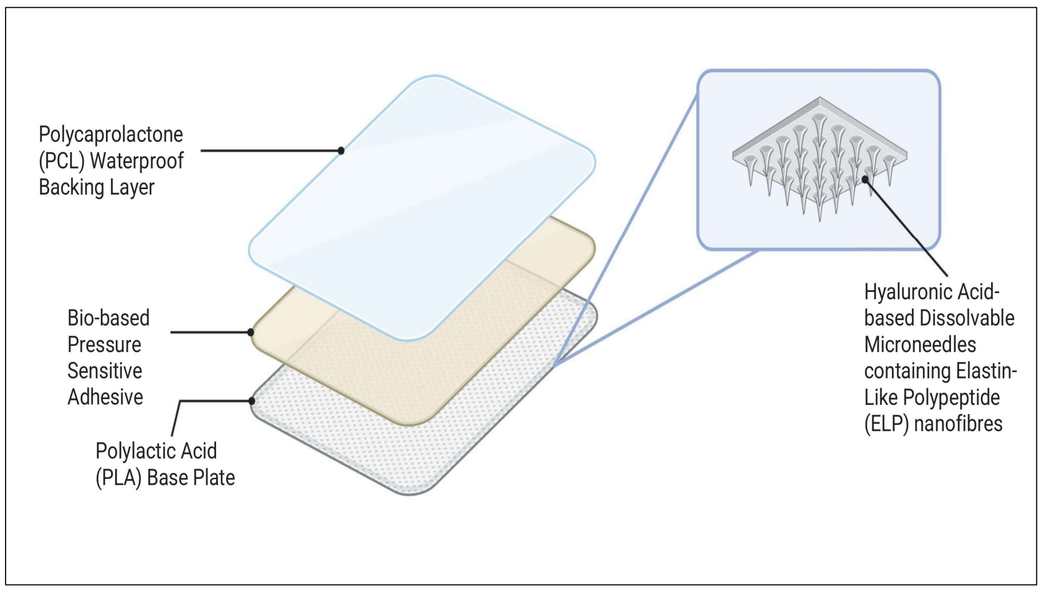
NanoSense: An Electrospun Nanofibre-Integrated Hyaluronic Acid Microneedle Patch for Localized Delivery of Diclofenac

Angeline Sia Sue Anne, Priyarubhini Krishnan

Priority Topic Area: **Engineering Biology**

1 – Enhancing RA Therapy

Rheumatoid Arthritis (RA) affects 18 million people worldwide, with 70% being women and 55% aged >55 years. This disease significantly impacts quality of life: 71% experience psychiatric conditions, are 3.6X more likely to be sick in bed and 53% less likely to be employed due to inflammatory episodes. However, current pain management via topical gels are limited by poor skin penetration due to the stratum corneum while oral medications result in systemic gastrointestinal side effects. This results in inefficient drug delivery to inflamed joints. To mitigate both limitations, we propose **NanoSense**, a bio-degradable patch that integrates microneedles and thermosensitive nanofibres that provides more effective targeted pain relief.



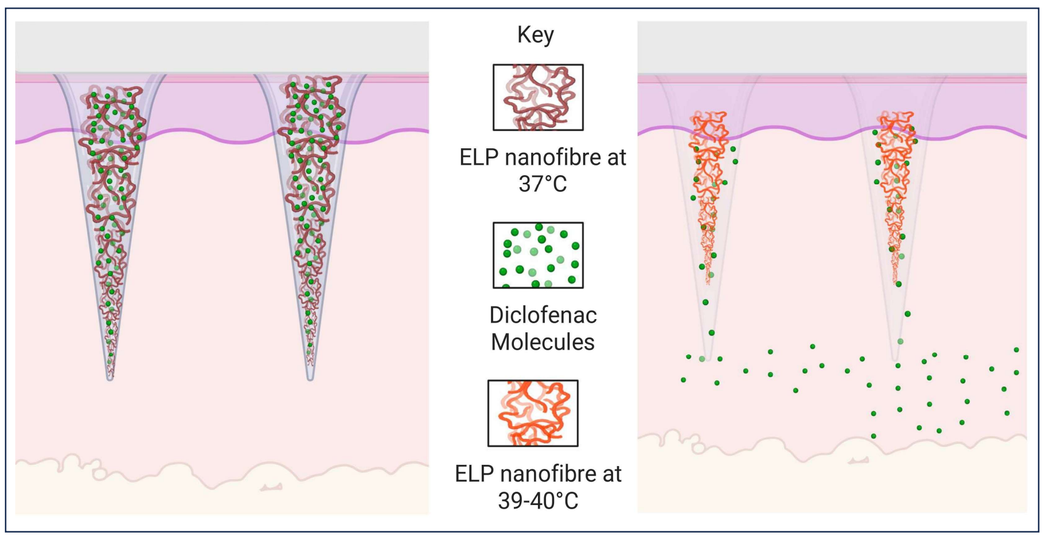
2 – Smart Nano Trigger Technology

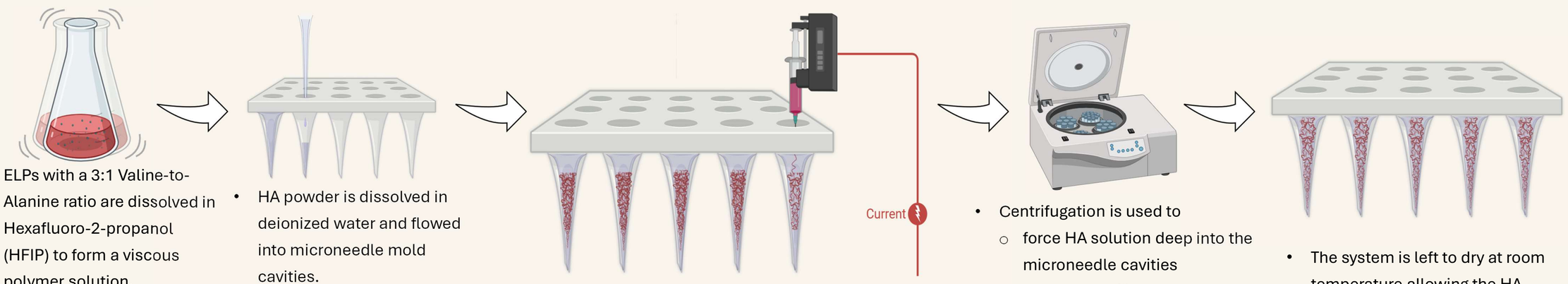
1. Elastin-Like Polypeptides (ELPs) with a 3:1 Valine-to-Alanine ratio are electrospun into nanofibres while embedding diclofenac within the polymer matrix.
2. Nanofibres are filled into Dissolving Microneedles (DMN) made of Hyaluronic Acid (HA).
3. Upon application to skin, the HA tips dissolve within minutes, leaving the thermosensitive ELP nanofibres deposited in the skin tissue.
4. Upon detecting a temperature change of 37°C to (39 - 40)°C, due to inflammation, the nanofibres shrink, releasing the drug, modelling the “sponge effect”.
5. Once inflammation subsides, the nanofibres rehydrate and re-expand, significantly reducing further drug release until subsequent inflammatory episodes.

3 – NanoSense Features

- **Biocompatible:** ELP is derived from human tropoelastin. Which reduces the risk of further irritation at sensitive RA joints due to its non-immunogenic properties.
- **Thermosensitive:** ELPs have a "Lower Critical Solution Temperature" (LCST). Below this temperature, the nanofibres are hydrated and swollen, when temperature increases, they collapse into a dense, hydrophobic structure that triggers drug release.
- **High Loading Density:** Each NanoSense patch can store up to 15.7mg of diclofenac.
- **Enhanced Permeation:** Microneedles are able to increase drug permeation up to 8x.
- **Increased Potency:** A single NanoSense patch matches the therapeutic impact of 120mg of conventional gel, as traditional topicals like Voltaren® Gel with 40mg diclofenac achieves only 6% penetration (2.4mg).
- **Sustainable & Biodegradable Components:**

PCL Backing
A hydrophobic polyester, biodegradable via microorganisms or enzymes.
Bio-PSA Adhesive
Uses an adhesive made from epoxidized soybean oil or modified starch. Compostable and skin-friendly.
PLA Base Plate
Firm, waterproof flooring made from fermented plant starch. Supports microneedles upright.
ELP Nanofibres
Synthesised from natural amino acids, they are easily broken down into non-toxic components by human enzymes.





- ELPs with a 3:1 Valine-to-Alanine ratio are dissolved in Hexafluoro-2-propanol (HFIP) to form a viscous polymer solution.
- Diclofenac is dissolved into the solution
- HA powder is dissolved in deionized water and flowed into microneedle mold cavities.
- Typical concentration: 10–30% w/v HA solution
- Electrospun nanofibres are deposited into the microneedle cavities
- Centrifugation is used to
  - force HA solution deep into the microneedle cavities
  - ensure nanofibres concentrate in the needle tips
- The system is left to dry at room temperature allowing the HA matrix to harden.

4 – Advancing Sustainable Chronic Care

- **Utilizes biocompatible, biodegradable materials:** Generates 0g plastic waste compared to the 10-15g of plastic & laminate used in a single topical gel tube
- **Precise delivery to the targeted tissue:** Eliminates the 25% drug wastage typically trapped in the traditional topical gel tube packaging
- **Reduces medicinal wastage:** Minimizes harmful chemical runoff into groundwater due to lower drug loading
- **Reduces the frequency of patient purchases:** Lowers the overall economic burden of chronic RA care

5 – A Pain-Free Future

Collaborate with pharmaceutical research companies e.g. (Servier, Pfizer) to:

- Optimize nanofibre drug loading capabilities to maximize patch’s potency
- Evaluate penetration efficiency using ex vivo skin models
- Measure local and systemic drug levels
- Optimize cost effective manufacturing, supply chain and packaging
- Conduct clinical trials to assess practical usability

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