National Alliance for Water Innovation

Porous Polymer Networks and Membranes for PFAS and Selenium Removal from Water

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Goals: To remove PFAS and Se from water to acceptable levels while achieving pipe-parity with current technologies

Current PFAS Treatment Technologies

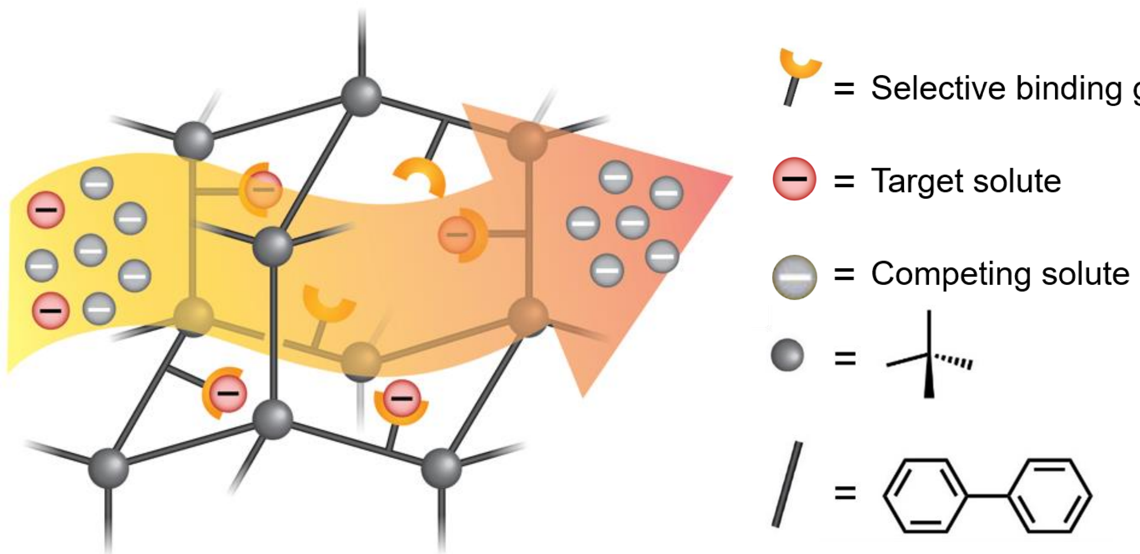
- Granular activated carbon or anion exchange resins
- Low capacity and selectivity, impaired by complex water matrices

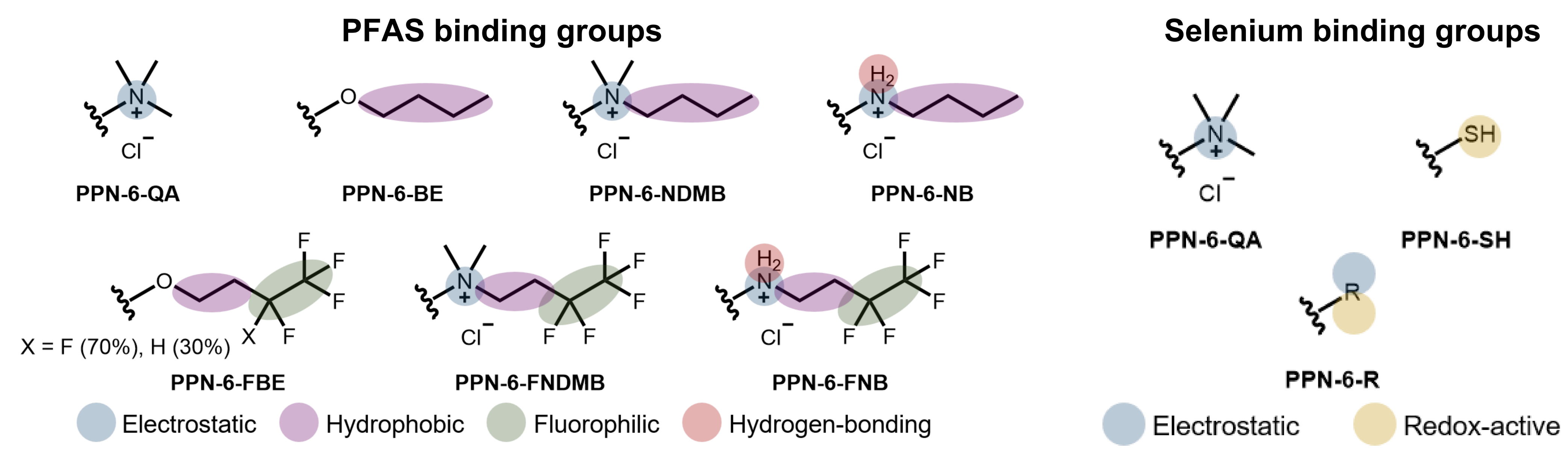
Current Se Treatment Technologies

- Reduction to Se^0 by zero-valent iron and bioreactors
- Slow, low capacities, large volumes of contaminated sludge

Our Approach

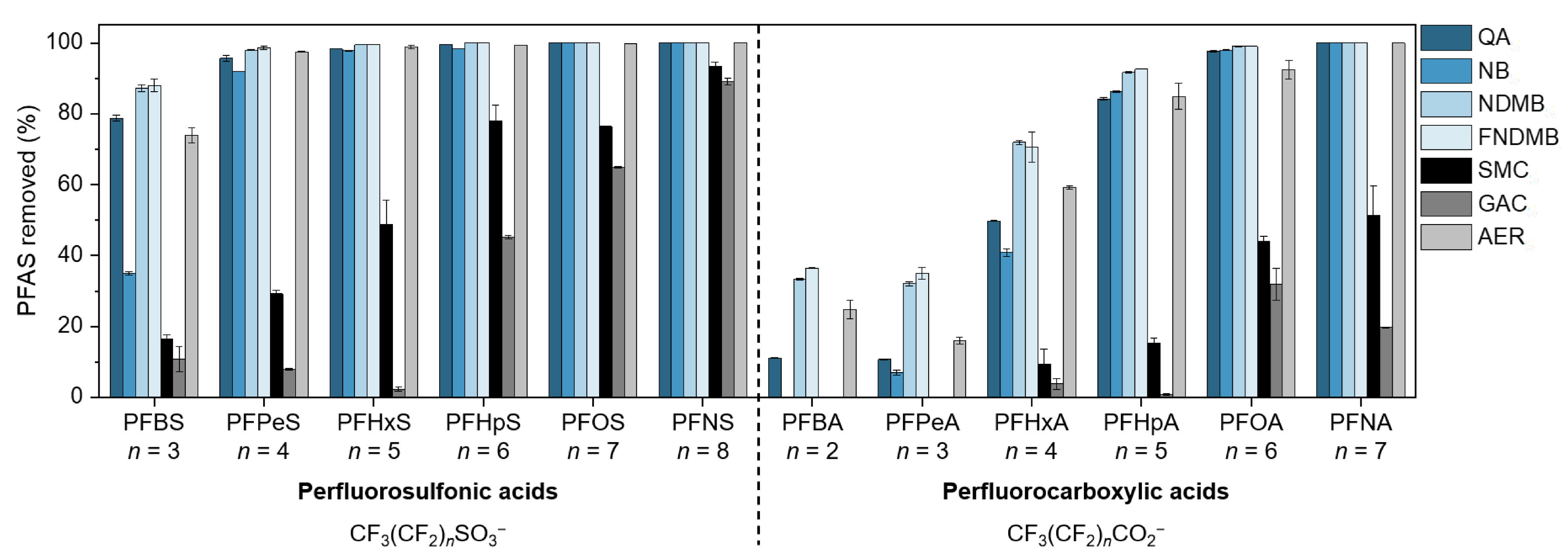
- Functionalize PPNs with PFAS- or Se-selective binding groups to leverage electrostatic, hydrophobic, fluorophilic, H-bonding, redox, or chelating interactions
- These PPNs can then be incorporated into composite membranes and pellets for efficient flow-through removal of contaminants[1]

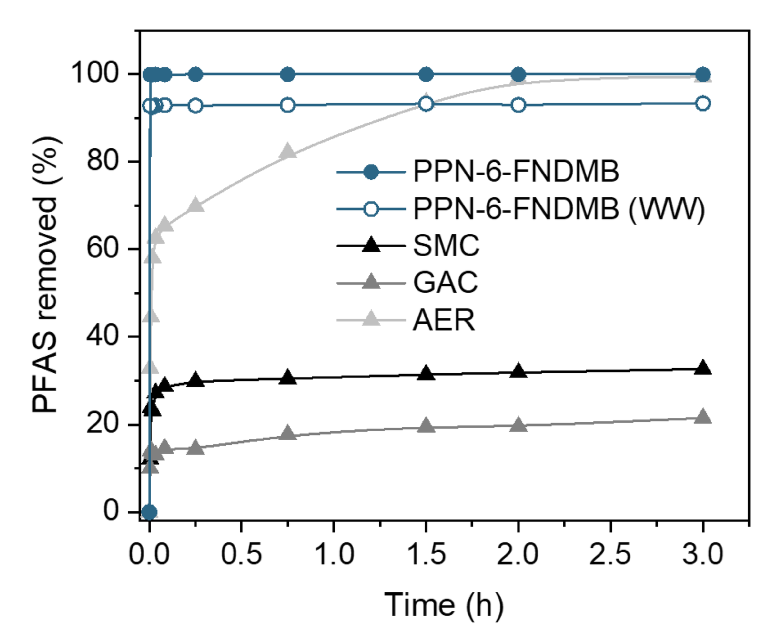


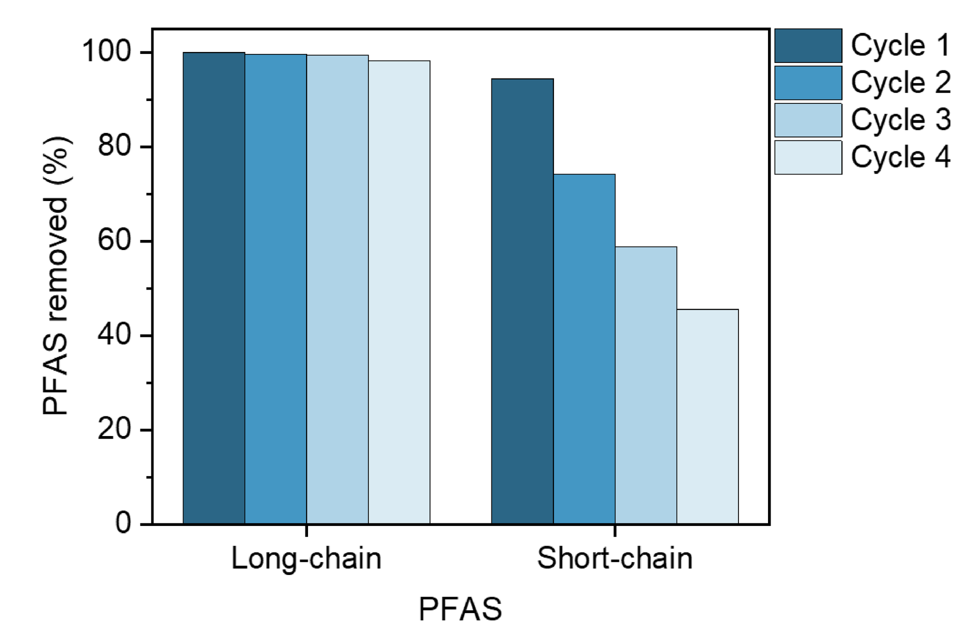


PFAS Removal

- Electrostatic and hydrogen-bonding interactions drive short-chain PFAS adsorption while hydrophobic and fluorophilic interactions boost long-chain adsorption
- PPNs outperform commercial adsorbents (GAC, SMC, AER) in terms of adsorption capacity, kinetics, and selectivity over competing solutes

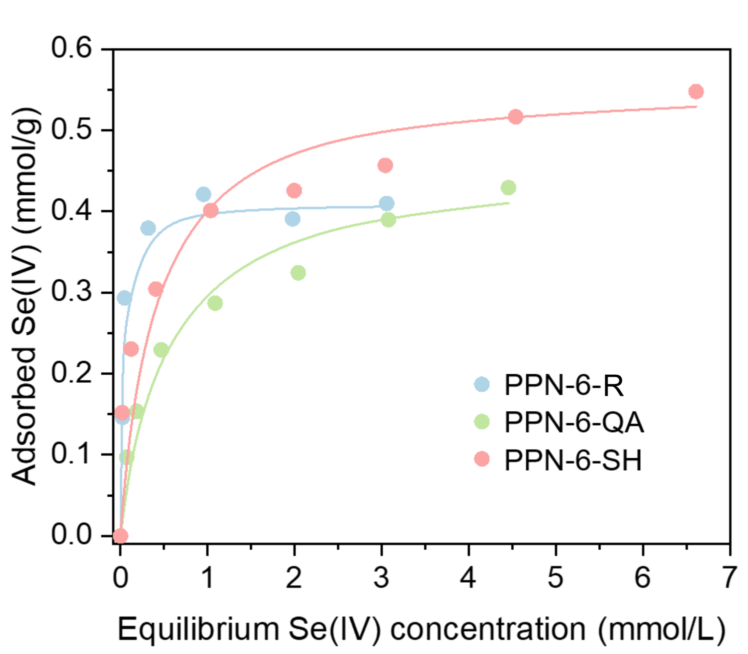


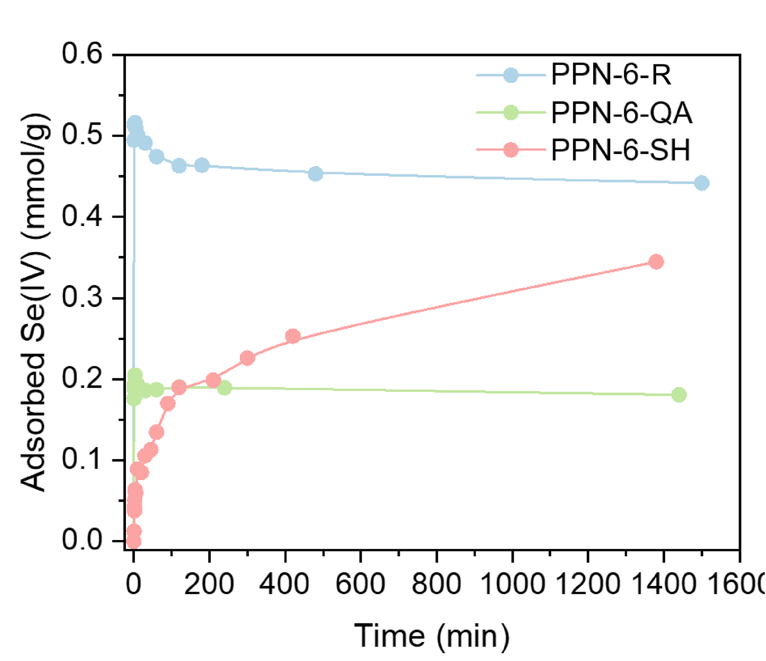


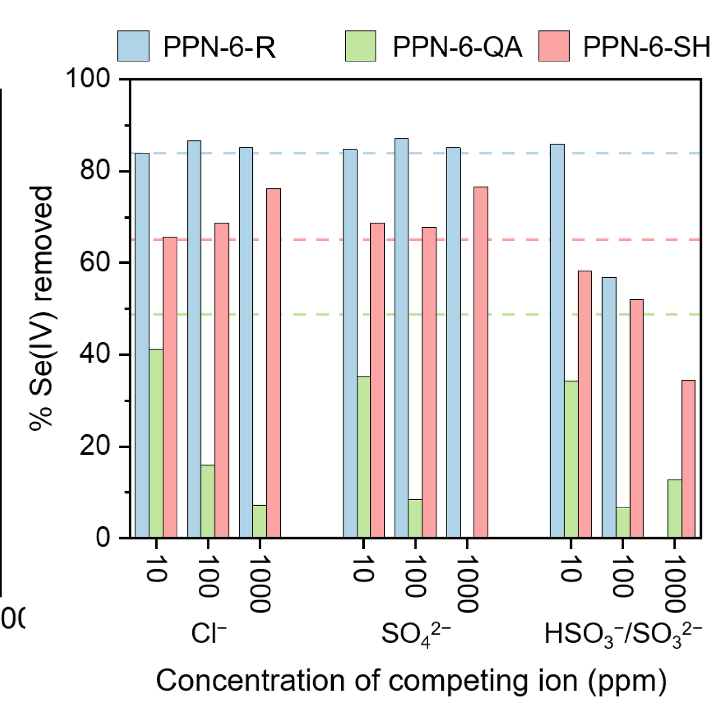


Selenium Removal

- Electrostatic interactions lead to rapid Se uptake, redox interactions lead to selective Se uptake, and a combination leads to fast and selective Se uptake
- PPN-6-R also shows uptake of Se(VI), but selectivity is an issue due to lack of Se reduction

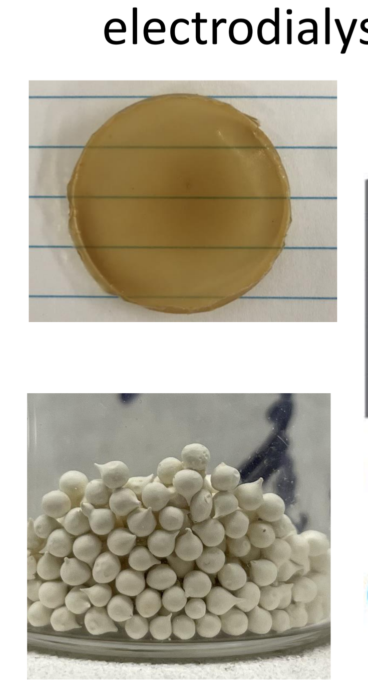


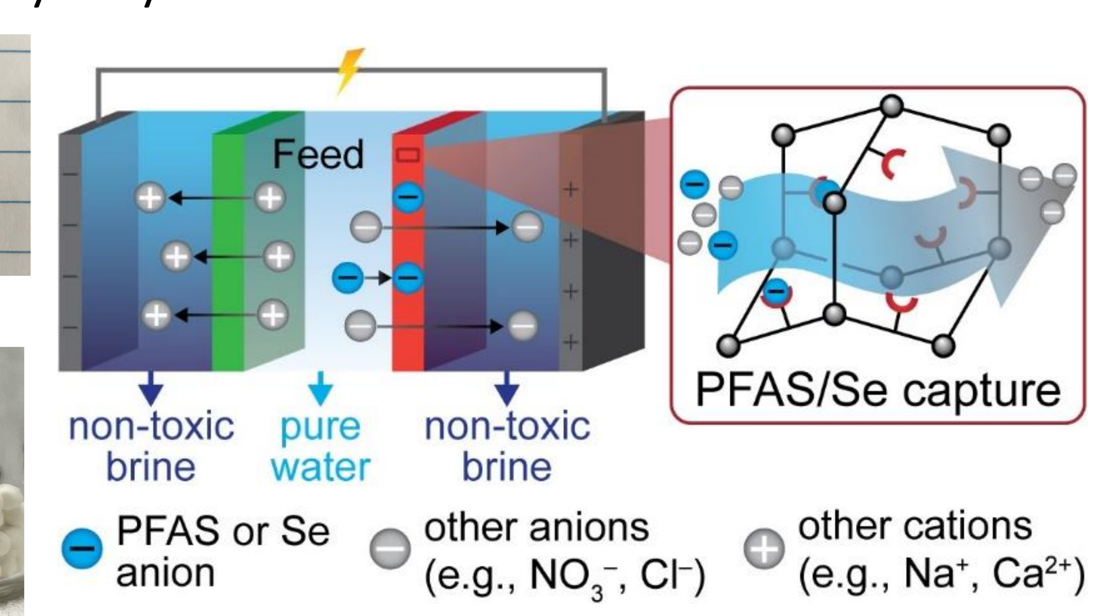




Pellets and Membranes

- Successfully incorporated PPNs into pellets and membranes
- Flow-through testing underway in columns and electrodialysis systems





NAWI CONNECTIONS

Period of Performance: March 2022 – March 2025.

Challenge Area/Topic Area: Materials and Manufacturing Topic Area

This project is focused on the development of novel adsorbents for the removal of Se and PFAS from contaminated water. The functionalization of porous polymer networks will generate high-performance materials that achieve pipe-parity for these separations.

NAWI Leverage:

NAWI has allowed for a diverse team of experts from industry and academia to be assembled to work towards these challenging separations.

KEY FINDINGS AND CONCLUSIONS

Subtitle: Tuning binding site chemistry enhances PFAS and Se adsorption.

Key Findings:

PFAS adsorption

- Electrostatic and hydrogen-bonding interactions are essential for short-chain PFAS adsorption.
- Combined with electrostatic interactions, hydrophobic and fluorophilic interactions increases long-chain PFAS adsorption, but has little effect on short-chain uptake.
- Fluorophilic interactions lead to stronger PFAS binding than hydrophobic interactions.

Selenium adsorption

- Electrostatic interactions lead to rapid adsorption kinetics but low Se selectivity.
- Redox interactions via thiol groups lead to selective Se adsorption but slow kinetics.
- A combination of electrostatic and redox interactions has synergistic effect of leading to both fast and selective adsorption of Se(IV).

Mixed matrix membranes and pellets

- Membranes for electrodialysis containing functionalized PPNs can be reproducibly fabricated.
- Adsorption and electrodialysis tests demonstrate retained adsorption capacities in the membranes.
- Second generation pellets have been successfully fabricated and are currently being tested for PFAS and Se adsorption in column experiments.

Conclusions: Exciting progress on both the fundamental and applied aspects of PFAS and selenium separations.

For fundamental science, the chemical mechanisms by which PFAS and Se are bound has been experimentally probed. This will guide the design of future adsorbents for these and other contaminants. For application, the PPNs out-perform commercial adsorbents and have been shown to be cost-competitive with existing technologies. Successful incorporation of the PPNs into membranes and pellets demonstrates commercializability and the ability to be implemented in existing treatment systems.

REFERENCES

1) Uliana, A. A.; Bui, N. T.; Kamcev, J.; Taylor, M. K.; Urban, J. J.; Long, J. R. Ion-Capture Electrodialysis Using Multifunctional Adsorptive Membranes. *Science* **2021**, *372*, 296–299

ACKNOWLEDGEMENTS

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