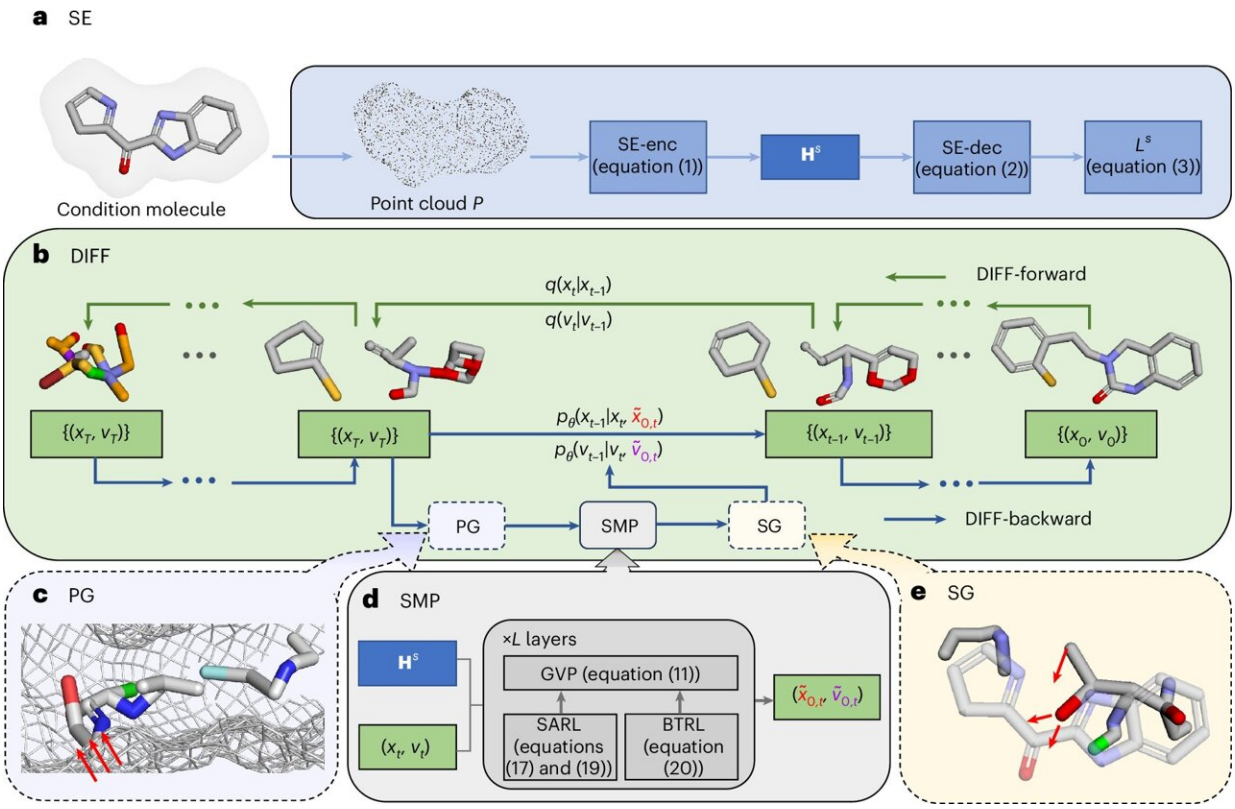
Generative AI is on track to shape the future of drug design

May 12 2025, by Tatyana Woodall



Model overview of DiffSMol. Credit: *Nature Machine Intelligence* (2025). DOI: 10.1038/s42256-025-01030-w

Using advanced artificial intelligence, researchers have developed a novel method to make drug development faster and more efficient.

In a new paper, Xia Ning, lead author of the study and a professor of biomedical informatics and computer science and engineering at The Ohio State University, introduces DiffSMol, a generative AI model capable of generating realistic 3D structures of small molecules that can serve as promising drug candidates.

The study is published in *Nature Machine Intelligence*.

DiffSMol works by analyzing the shapes of known ligands—molecules that bind to protein targets—and using these shapes as conditions to generate novel 3D molecules that better bind to the protein targets. Study results showed that when used to create molecules with the potential to quicken the drug-making process, DiffSmol has a 61.4% success rate, outperforming prior research attempts that achieved success about 12% of the time.

"By using well-known shapes as a condition, we can train our model to generate novel molecules with similar shapes that don't exist in previous chemical databases," said Ning.

Once DiffSMol learns the shapes of these ligands, the team's model can also tailor those new molecules to encourage certain binding characteristics. According to the paper, this suggests the model could modify them to have more favorable drug-like properties, altering aspects like their synthesizability or toxicity.

It takes about a decade for a drug to be developed and brought to market, but shortening that time could open up new paths to develop novel pharmaceuticals and agrochemical agents for use in many different industries. Chiefly, compared to existing computational methods used to design drugs, DiffSMol takes only one second to generate a single molecule, said Ziqi Chen, co-author of the study and a former doctoral student in computer science and engineering at Ohio

State.

"Generative AI models have the potential to substantially expedite this process and improve cost efficiency," said Chen.

To demonstrate DiffSMol's abilities, researchers conducted case studies on molecules used in two crucial drug targets, one called cyclin-dependent kinase 6 (CDK6), which can regulate cell cycles and disrupt cancer growth, and neprilysin (NEP), which is used in therapies aimed at slowing the progression of Alzheimer's. Their results revealed that the molecules DiffSMol created would likely be very effective, said Ning.

"It's very encouraging for us to find molecules with even better properties than known ligands," she said. "It indicates that our developed models have great potential in identifying good drug candidates."

The researchers also made DiffSMol's code available for other scientists to use.

At the moment, DiffSMol is still only able to generate new molecules based on shapes of previously known ligands, which is a limitation the team hopes to overcome in future work. Further research will also be aimed at improving the model's ability to learn from complex molecule data and generate molecules that exhibit a wider range of potential interactions.

Despite the need for more testing, the team anticipates that continued leaps in AI will one day allow their work to reach new heights, partly due to AI's global rise in popularity.

"Nowadays, people are applying these advanced models to molecule generation, to chemistry, to nearly all science areas," said Ning. "This area grows really fast and I don't see it slowing down anytime soon."

More information: Ziqi Chen et al, Generating 3D small binding molecules using shape-conditioned diffusion models with guidance, *Nature Machine Intelligence* (2025). DOI: 10.1038/s42256-025-01030-w

Provided by The Ohio State University