● Awad distinguishes between different "types" of AI. What classification scheme does the paper use, and why do these types matter for scientific research?

Awad uses a Paradigm/Application classification scheme. In the first section, the author categorizes the different types of AI based on the paradigms of each, such as foundational, decision-oriented, and cross-cutting. Foundational paradigms include descriptive AI, predictive AI, and generative AI. The Decision-Oriented paradigm contains optimization AI and prescriptive AI. Cross-cutting consists of privacy-aware AI, causal AI, and explainable AI. In section 2, the author gives examples of applications of the different AIs belonging to the paradigms. They matter for science because all types of AI within these paradigms are actively playing a part in the way we do scientific research.

Foundational AI plays a big role in automating pattern recognition, connection-making, and discovering underlying themes, making it easier for researchers to work with complex, larger datasets. For example, predictive AI reduces the need for "manual data" by learning patterns from raw data. Along with this, descriptive AI assists researchers with comprehending multimodal datasets by discovering themes and synthesizing strategically. Awad says this makes it "especially valuable in the early stages of scientific research, when the goal is to uncover what insights the data might hold". Generative AI holds the power to generate content designed to be realistic and mimic real data, which allows researchers to make major breakthroughs without breaching privacy concerns. The Decision-Oriented Paradigm contains AI's that go beyond observing, generating, and drawing conclusions. It finds the most optimal solutions under constraints while providing different ways of doing things with pros/cons of each. Optimization AI doesn't just "assist with scientific reasoning," but it makes decisions that might be both different and smarter than human intuition. Lastly, Cross-cutting AI balances privacy/security with scientific discovery. For example, privacy-aware AI protects sensitive data, causal AI helps identify true cause and effect relationships, and explainable AI makes results transparent and trustworthy, supporting reuse across studies. This is big for scientific discovery.

● Does Awad make a clear distinction between AI as a tool and AI as a scientific collaborator? If so, what are the differences and what are some examples given to support the differences? Do these examples suggest a real shift in how science is conducted, or mostly an extension of existing methods?

Yes Awad does make a clear distinction between AI as a tool and AI as a scientific collaborator specifically after walking us through the paradigms and their main functionalities in the scientific world. Awad states that "AI is influencing every stage of the scientific method" comparing and contrasting both casual and explainable AI with collaborative AI stating collaborative AI "fosters new kinds of partnerships – across institutions, disciplines, and even between humans and machines". From my understanding, Awad categorizes AI as a tool to scientific research that automates, optimizes, and helps us humans work with data in a way that minimizes our input. AI

as a tool can help minimize complexity, time, and computation as well as fill in gaps that can take us from a question mark to a new point of view.

However, AI as a scientific collaborator goes beyond assisting with scientific research and instead drives it and can even take it into new directions. Awad says advanced systems now work in generating hypotheses, “casual reasoning and even aspects of experimental design’, some of which require little human input. The author believes that the responsibility of scientific work will be “shared’ by researchers and AI collaborators. One example of AI as research collaborators would be in Meta-scientific AI. In this type of system, the AI elevated the scientific process by operating in agentic behavior allowing them to adapt their practices based on the environment around them. They can make decisions and prioritize tasks in a way that mirrors a beginner researcher. Awad says “rather than being just advanced tools, AI systems are beginning to act as collaborators in the discovery process.” Meanwhile, AI as tools “collectively enhance the analytical and creative dimensions of scientific work.” An example of this would be AI assisting with complex experiments or simulations using tools like neural networks or Gaussian processes. These tools are used to create system behavior that realistically mimics real data at a cheaper cost of most time and money. This enables researchers to test and simulate different environments without the heavy lifting of constructing everything themselves.

I believe these examples do suggest a real shift in how science is conducted by the way they are an extension of already existing methods. The methods we did have before AI were strong, and with AI tools and collaborators I see that we are elevating and strengthening our old processes. This is a recipe for innovation and change, which is why I say there will be a real shift in how science is conducted. We already see from these examples that AI is upscaling science as we know it in both automation and discovery. This upscale is bound to keep evolving as both our systems and our interactions with them grow.

● What are some limitations or risks of using AI in science? How do these relate to issues such as interpretability, bias, reproducibility, or theory formation?

I feel like the risks of AI usage in science largely lie in where we trust that its capabilities include human understanding. We as humans understand AI systems can do things that we can’t do, however, we tend to forget it’s the same the other way around. Awan points out that there are risks in the things that AI cannot replicate asking who verifies all the “machine-derived knowledge”. He also points out how important it is to preserve the ethical, human-intuitive parts of science that “AI cannot replicate”. There is danger in not knowing the line between allowing AI to better assist with innovation and handing over too much power in doing so.

For example, in feature engineering, “black boxes” are described as results obtained without clear recognition about how they were obtained. In large and important data sets, how can we verify all results are accurate and meaningful? This directly corresponds to reproducibility. If we

don’t know how the results were fully produced, how can we recreate them or the system that produced them? Another issue like interpretability bias reflects that subtle biases can be embedded into AI generated content. For example, natural language processing equips computers with the ability to “read and analyze large volumes of texts”. However, NLP tools have displayed “unintentional societal biases” directly regarding gender and race. An AI system doesn’t have the same humanity and ethical awareness it takes to recognize when something is discriminatory. In terms of theory formation, I believe the issue lies in the core principles of safeguarding and fact checking AI generated theories. It largely ties into allowing too much trust with AI systems and not being able to verify information or content derived from a machine.

● According to Awad’s arguments, is AI more likely to accelerate scientific discovery or to reshapethe scientific method itself? Do you agree or disagree?

I disagree because I feel like the usage of AI systems at present reshape the scientific method itself. Most of the text talks explicitly about the ways different kinds of AI in their respective paradigms automate, enhance, and innovate steps in the scientific method. I can see that AI can accelerate scientific discovery, however, most of the evidence leads to the likeliness of the scientific method being reshaped by AI. Awad mentions that “AI for scientific discovery” is a crosscutting enabler of innovation which prompts institutions to rethink research methodologies and invest in computational infrastructure” (National Academies of Sciences, Engineering, and Medicine et al., 2023). However, we still have to acknowledge the issue of knowing how much trust to put into LLMS and AI systems. I don’t feel like us humans have figured out a way to guarantee AI content is accurate and ethically sound all of the time. For that reason, we can’t completely rely on it for accelerating scientific discovery. The issues such as interpretability bias, reproducibility, and theory remain a profound blockage in trusting AI systems completely. I do agree that the data and content AI systems produce can be incredibly accurate and entirely helpful to scientific discovery. However, I am saying scientists should continue to prioritize keeping the general population's trust in science. We are still getting to know the ins and outs of using AI.